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ATMOSPHERIC WATER VAPOR ABSORPTION AT 12 CO_2 LASER FREQUENCIES

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ABSTRACT

This report summarizes the measurements which were made on the absorption of CO_2 laser radiation by pressure-broadened water vapor samples. The twelve laser frequencies which were used were located in the 9.4 μm band. Water vapor temperatures used in this program were 25, 30, and 35°C.

CONTENTS

INTRODUCTION

A long-path, multiple-traversal absorption cell was used in this study of the attenuation of CO_2 laser radiation by atmospheric water vapor. Table I shows the twelve laser lines from the 10^00-02^00 CO_2 band near 9.4 μm which were used to probe pressure-broadened water vapor samples at temperatures of 25, 30 and 35 degrees centigrade.

All water vapor samples were broadened with an 80:20 mixture of nitrogen and oxygen. The mixture was free of CO_2. Path lengths through the sample were either 1.186 km or 1.359 km in this experiment.

Table 1
Laser Line identification and grating settings

Laser Line	Grating Setting	Frequency (cm^{-1})
P(10)	6278	1055.625
P(12)	6225	1053.924
P(14)	6175	1052.196
P(16)	6125	1050.441
P(18)	6080	1048.661
P(20)	6025	1046.854
P(22)	5966	1045.022
P(24)	5923	1043.163
P(26)	5878	1041.279
R(26)	6978	1082.296
R(28)	7011	1083.479
R(30)	7040	1084.635

EXPERIMENTAL APPARATUS

1. Laser

The laser used in this experiment was a sealed-off, cw Sylvania 948 CO_2 laser which had been modified to be grating tunable for single-line operation and electronically stablized to maintain stable frequency

output at line center. The resonant cavity, shown in Figure 1, consists of a flat grating, a spherical turning mirror mounted on a PZT transducer, and a flat gallium arsenide output window.

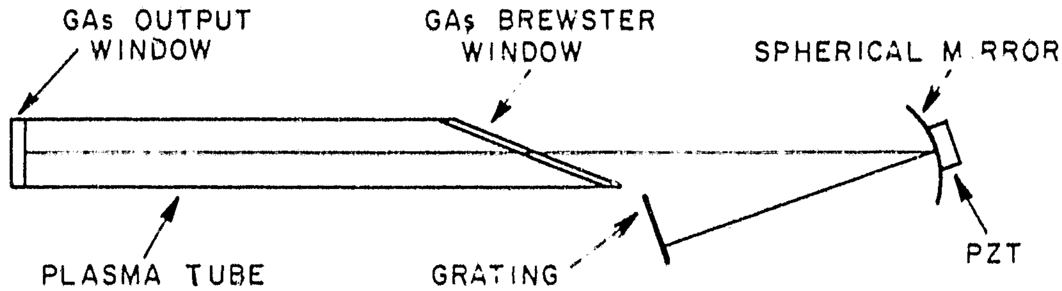

Figure 1. Laser resonant cavity.

The plasma tube and cavity optics were mounted on a 7.62 cm thick limestone slab to give the laser mechanical stability. A dust cover made from 0.9 cm thick plexiglass sheet protected the laser.

During our experiments, we found that all 9.4 μm band output frequencies of the laser operated better at cooler laser temperatures. Therefore, we installed a 5-qt. capacity refrigeration unit to cool the discharge tube. With this modification, all desired laser lines for this experiment were observed.

2. White Cell

The stainless steel absorption cell used to hold the water vapor samples is 12 m long and 0.6 m in diameter with 10.785 m between the mirrors. The multiple-reflection mirrors are 30 cm diameter, gold-coated Cervit with radii of curvature (10.785 m) matched to 1 mm. The mirrors are mounted on kinematic mounts designed for stability over a wide range of temperatures. Fine position control of the mirrors is provided by stepper motors which are manually or computer controlled. Path lengths of up to 2 km can be achieved.

The absorption cell temperature can be controlled over the range $-60^{o}C$ to $+60^{o}C$ with uniformity along the length of $\pm 0.5^{o}C$ at the extreme temperatures. For the cell temperatures used in this study, typical uniformity was $\pm 0.2^{o}C$. Control of the temperature is achieved by flowing a liquid coolant (methynol) through tubes welded to the cell walls. The liquid can be heated by resistive heater elements or cooled by a cascade mechanical refrigeration system. Molded urethane insulates the cell.

Since vibrations can limit the obtainable path length, the entire cell and its optical table are mounted on a frame of 12 inch I-beams which in turn are mounted on air cushion supports. The mirror mounts are fixed to the frame by stainless steel legs which pass through the cell body in flexible stainless steel bellows. This permits the cell body to expand and contract with temperature changes while leaving the mirrors fixed.

Water vapor was introduced into the cell by boiling liquid water from a reservoir. Dissolved gases such as CO_2 were removed from the water sample by pumping on the volume above the water before the container was attached to the cell. Verification of the water vapor partial was obtained by a General Eastern 1200 Series Hygrometer before each measurement series.

In this experiment, a buffer gas of artificial air was used to bring the total cell pressure to one atmosphere. The artificial air was produced by using 80% nitrogen and 20% oxygen by volume. The air was free of CO_2. A MKS Baratron type PDR manometer with a full scale accuracy of 0.1% was used for pressure monitoring.

3. Data Reduction System

Figure 2 shows the optical transfer system into the absorption cell and out of the cell to the detector. The two detectors shown are disc calorimeters with 2.54 cm apertures. The barrium fluoride beam splitter

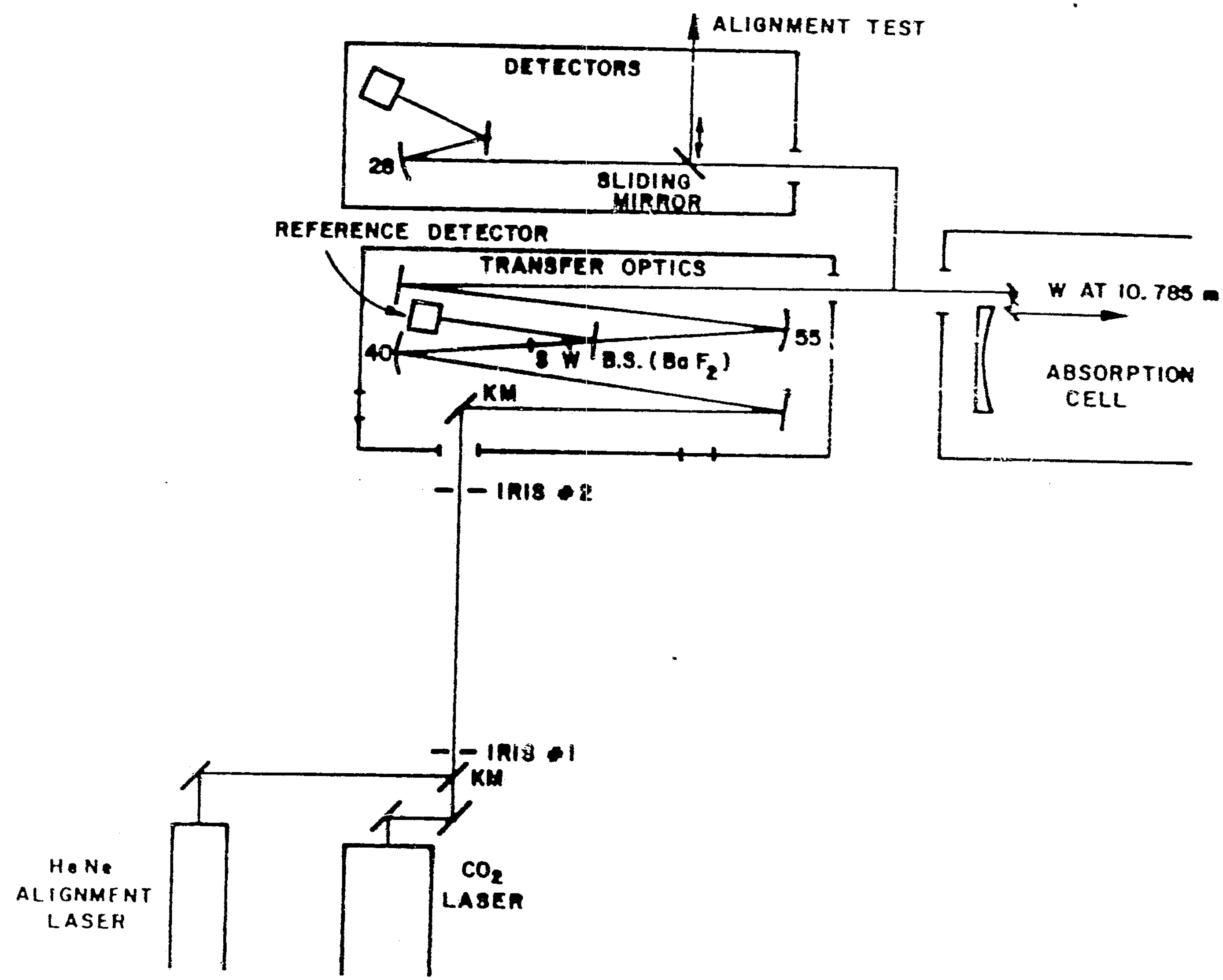

Figure 2. Experimental setup.

sends a portion of beam to the reference detector which monitors fluctuations in laser output power. The other portion of the radiation enters the absorption cell containing a known partial pressure of water vapor and finally falls on the second detector.

The outputs from the detectors are digitized in a IMSAI 8080 computer, the ratio of the signal detector divided by the reference detector is made, and the results averaged. This final number is recorded and eventually ratioed with a measurement taken by the same method with no water vapor in the cell to produce a transmittance value for each measured water vapor partial pressure. The absorption coefficient is then calculated from the transmittance data by the familiar

$$k = \frac{1}{L} \ln T$$

where k is the absorption coefficient in km^{-1}, L is the path length in km and T is the measured transmittance. For the range of transmittance values measured in this experiment, we estimate that random processes produced an uncertainty in the measured absorption coefficients of approximately $\pm 2\%$. Thus, nominal errors on the measured absorption coefficient are quoted as $\pm 2\%$.

EXPERIMENTAL RESULTS

Results of the measurements program are summarized in a series of tables and figures. Figures 3-36 show least square curve fits to the experimental data at 25, 30, and 35 degrees centigrade. The curve fits are of the form

$$k = Ap + Bp^2$$

where k is the absorption coefficient in km^{-1}, p is the partial pressure of water vapor in torr, and A and B are the fitting parameters. Table 2 gives a list of these parameters for each laser line at each sample

temperature. It also indicates the RMS error in the fit and a normalized error which is calculated as

$$\text{normalized error} = \text{RMS}\sqrt{\frac{N}{\Sigma k^2}}$$

where N is the number of data points and Σk^2 is the sum of the square of independent variable values.

From these fits, then, absorption coefficients at each laser frequency for each sample temperature and pressure can be calculated. These values appear in Table 3. Data sheets appear in Appendix A.

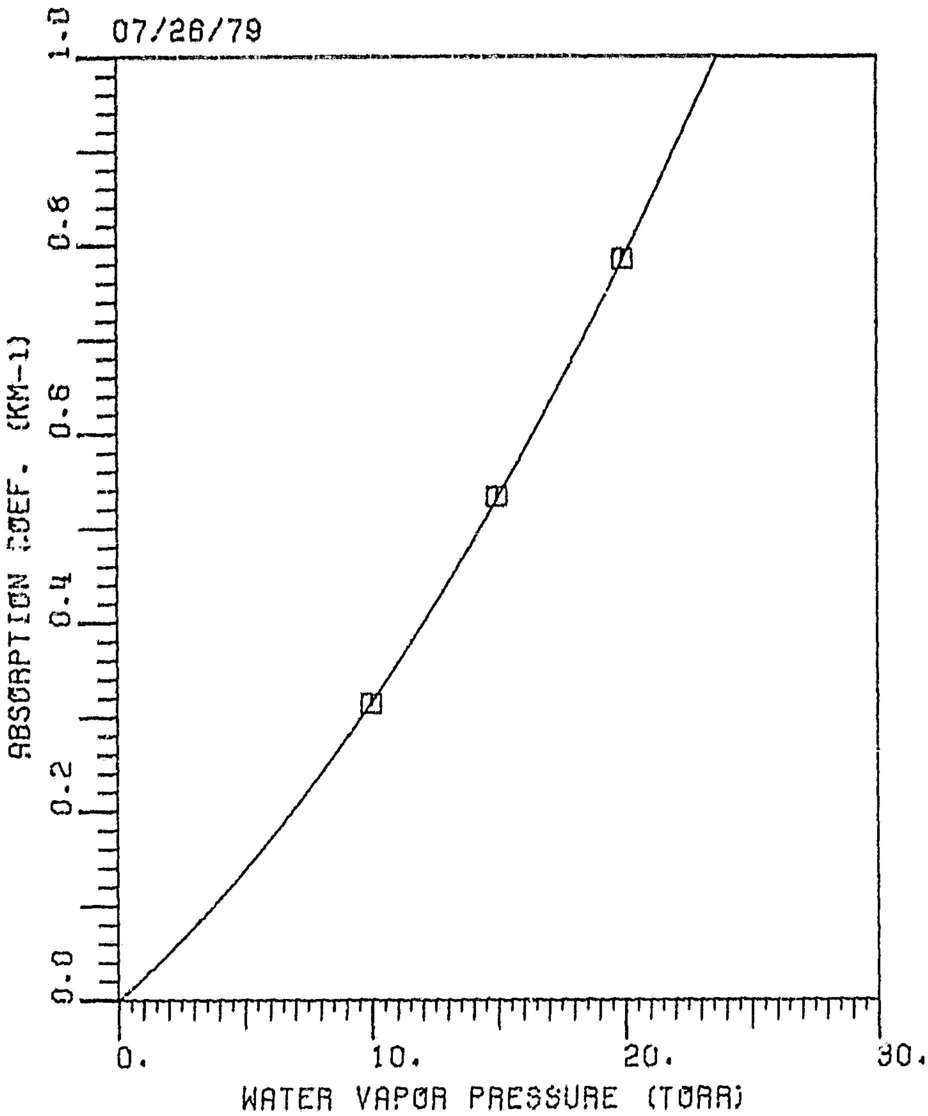

Figure 3. Absorption coefficient vs H_2O partial pressure for P(10) CO_2 laser line at 1055.625 cm^{-1} at 25°C.

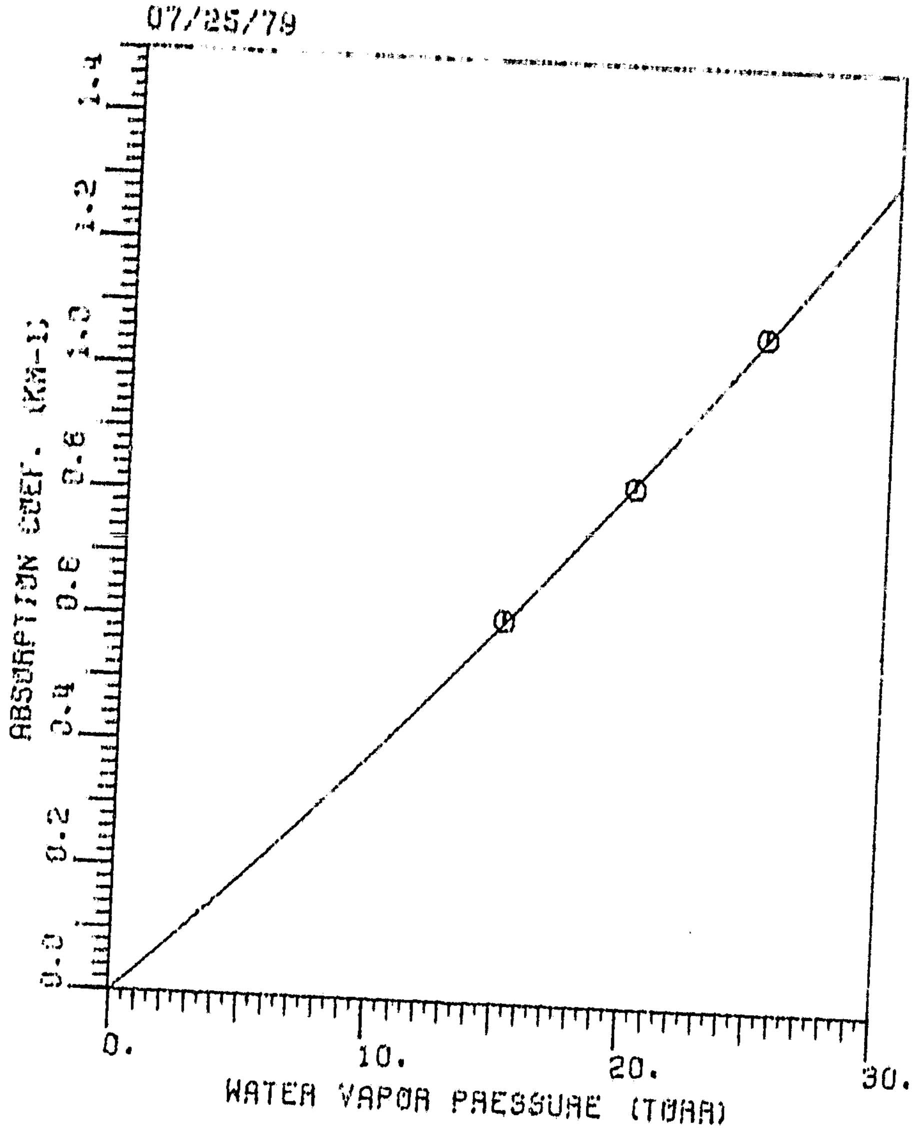

Figure 4. Absorption coefficient vs H_2O partial pressure for P(10) CO_2 laser line at 1055.625 cm^{-1} at 30°C.

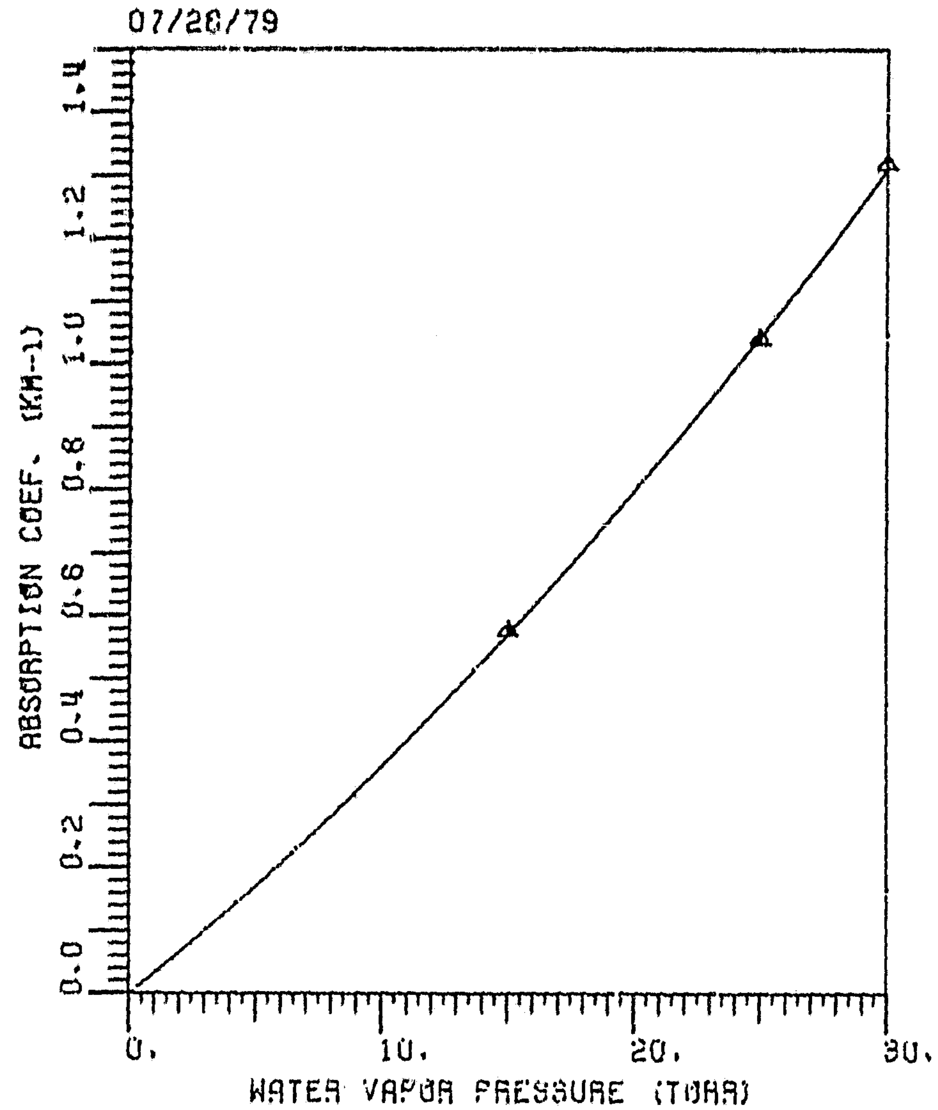

Figure 5. Absorption coefficient vs H_2O partial pressure for P(10) CO_2 laser line at 1055.625 cm^{-1} at 35°C.

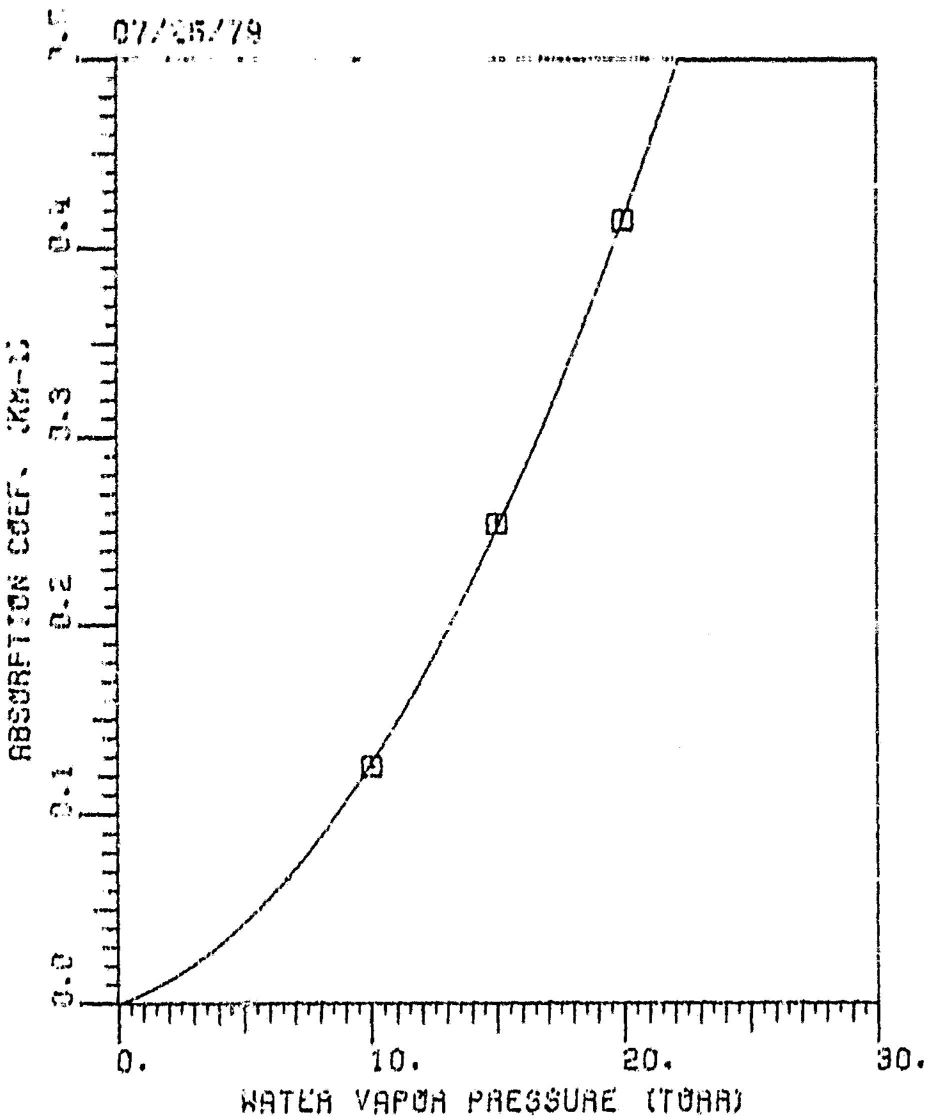

Figure 6. Absorption coefficient vs H_2O partial pressure for P(12) CO_2 laser line at 1053.924 cm^{-1} at 25°C.

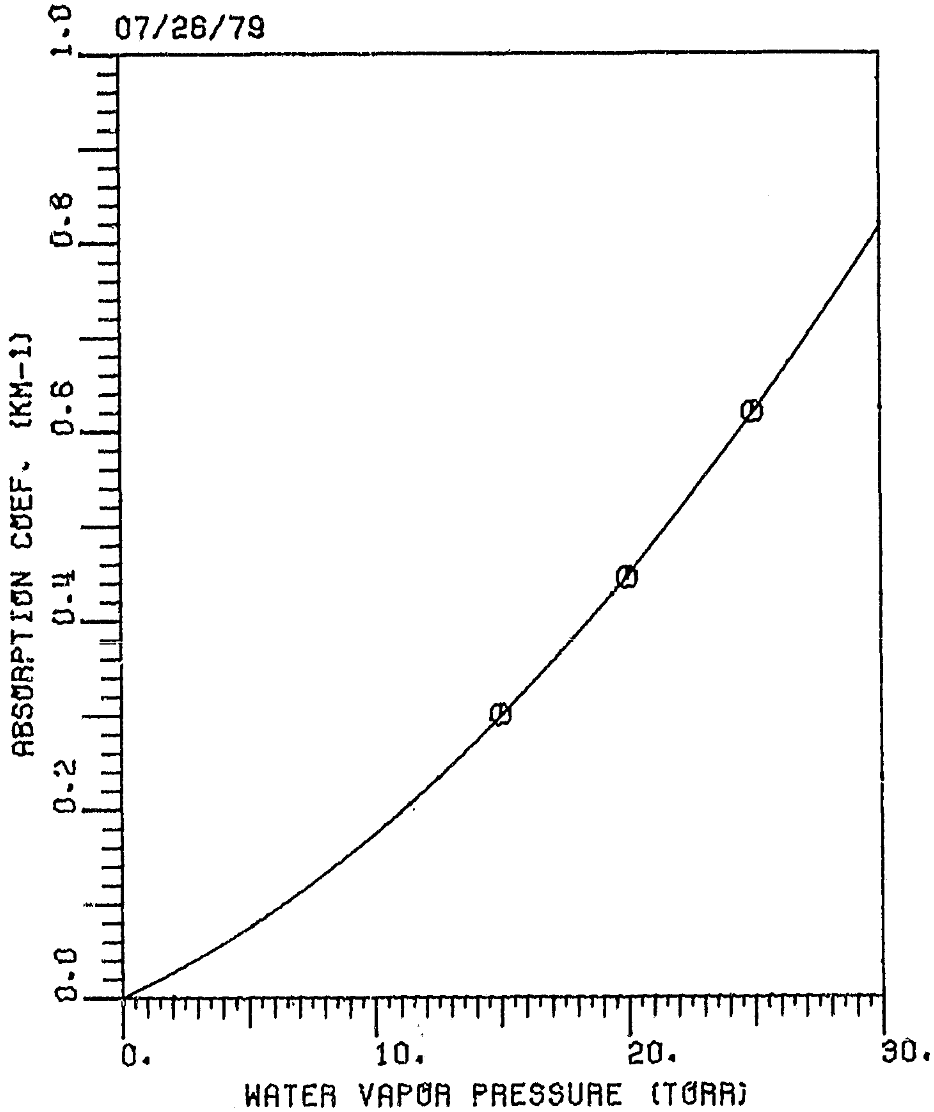

Figure 7. Absorption coefficient vs H_2O partial pressure for P(12) CO_2 laser line at 1053.924 cm^{-1} at 30°C.

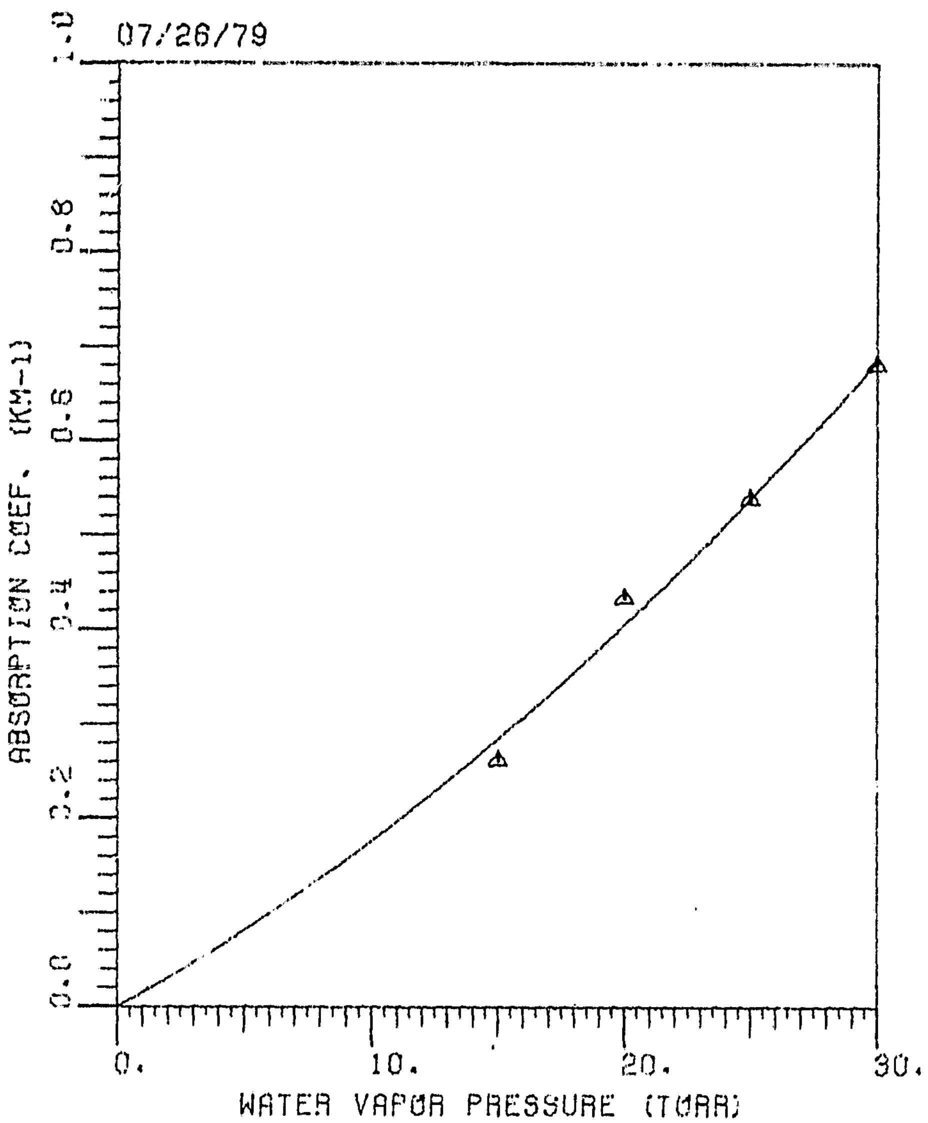

Figure 8. Absorption coefficient vs H_2O partial pressure for P(12) CO_2 laser line at 1053.929 cm^{-1} at 35°C.

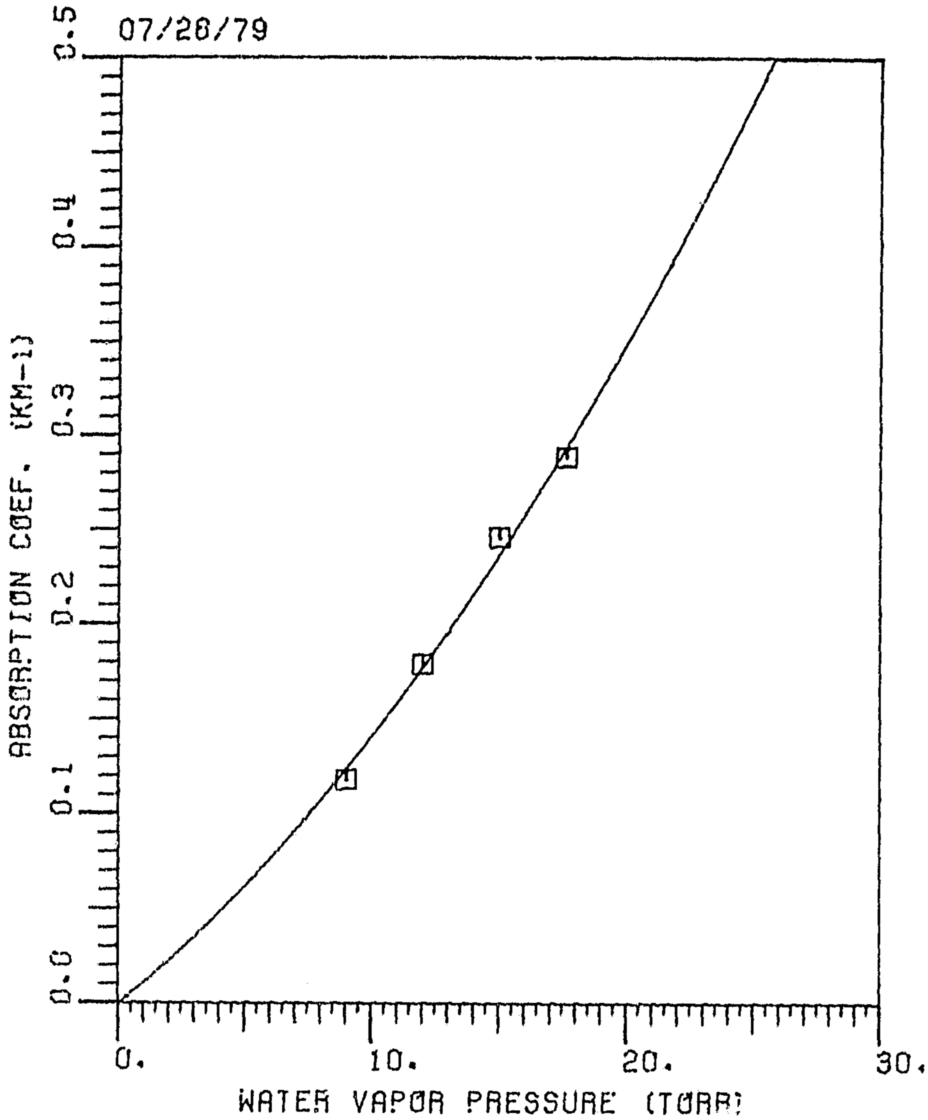

Figure 9. Absorption coefficient vs H_2O partial pressure for P(14) CO_2 laser line at 1052.196 cm^{-1} at 25°C.

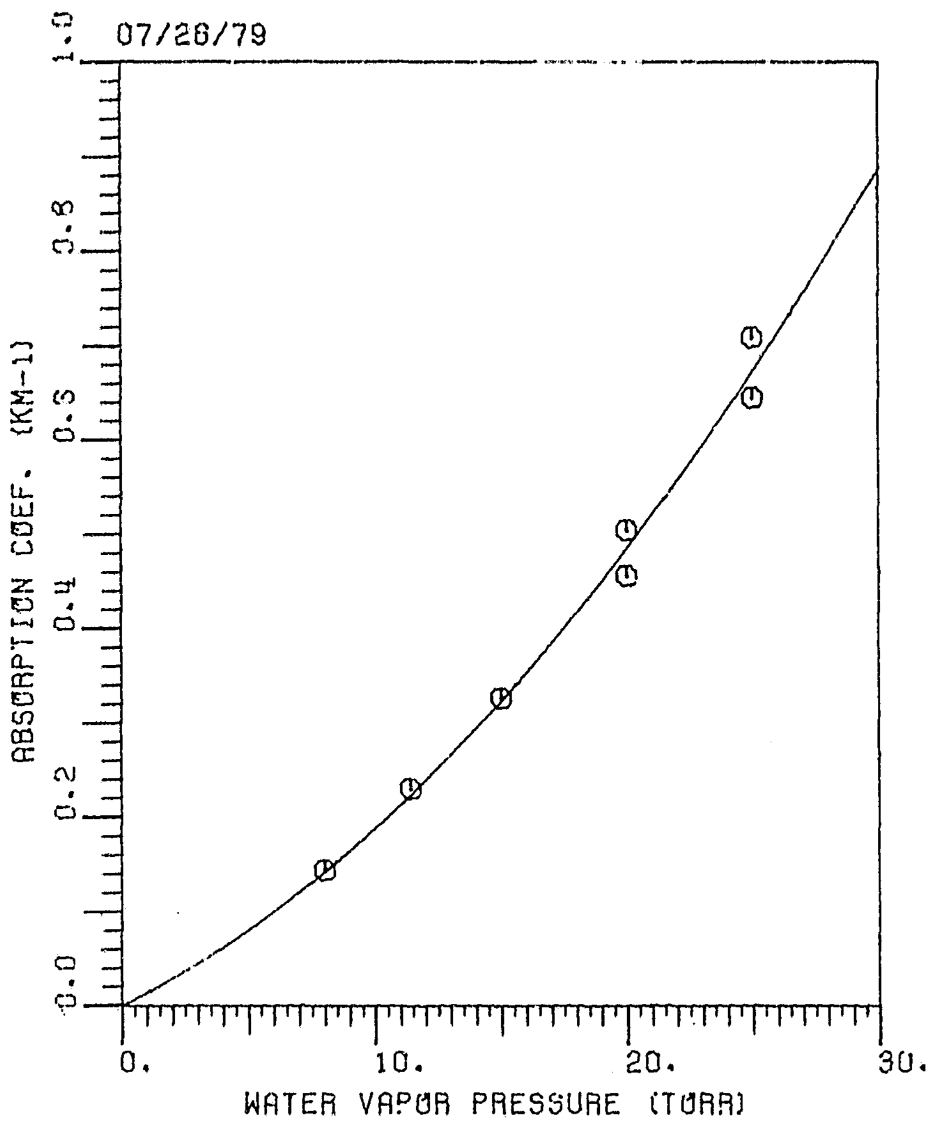

Figure 10. Absorption coefficient vs H_2O partial pressure for P(14) CO_2 laser line at 1052.196 cm^{-1} at 30°C.

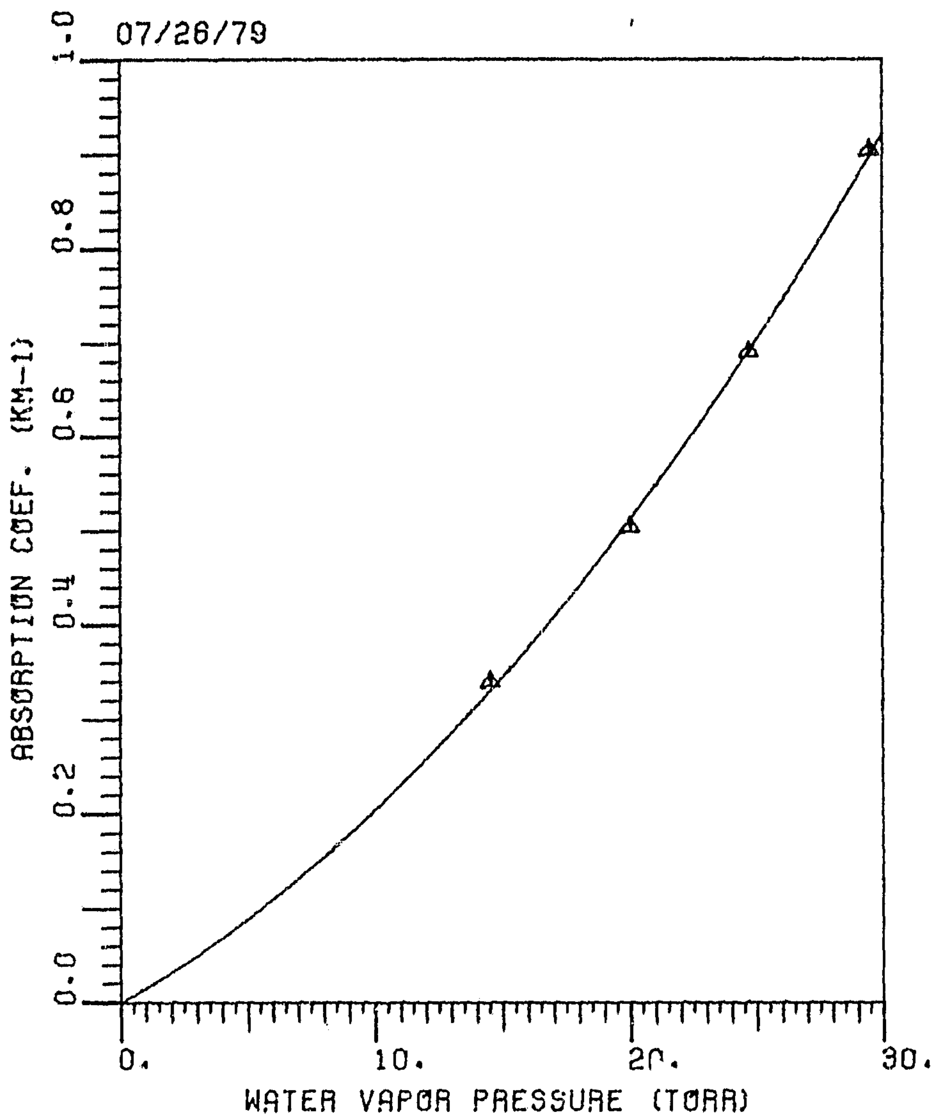

Figure 11. Absorption coefficient vs H_2O partial pressure for P(14) CO_2 laser line at 1052.196 cm^{-1} at 35°C.

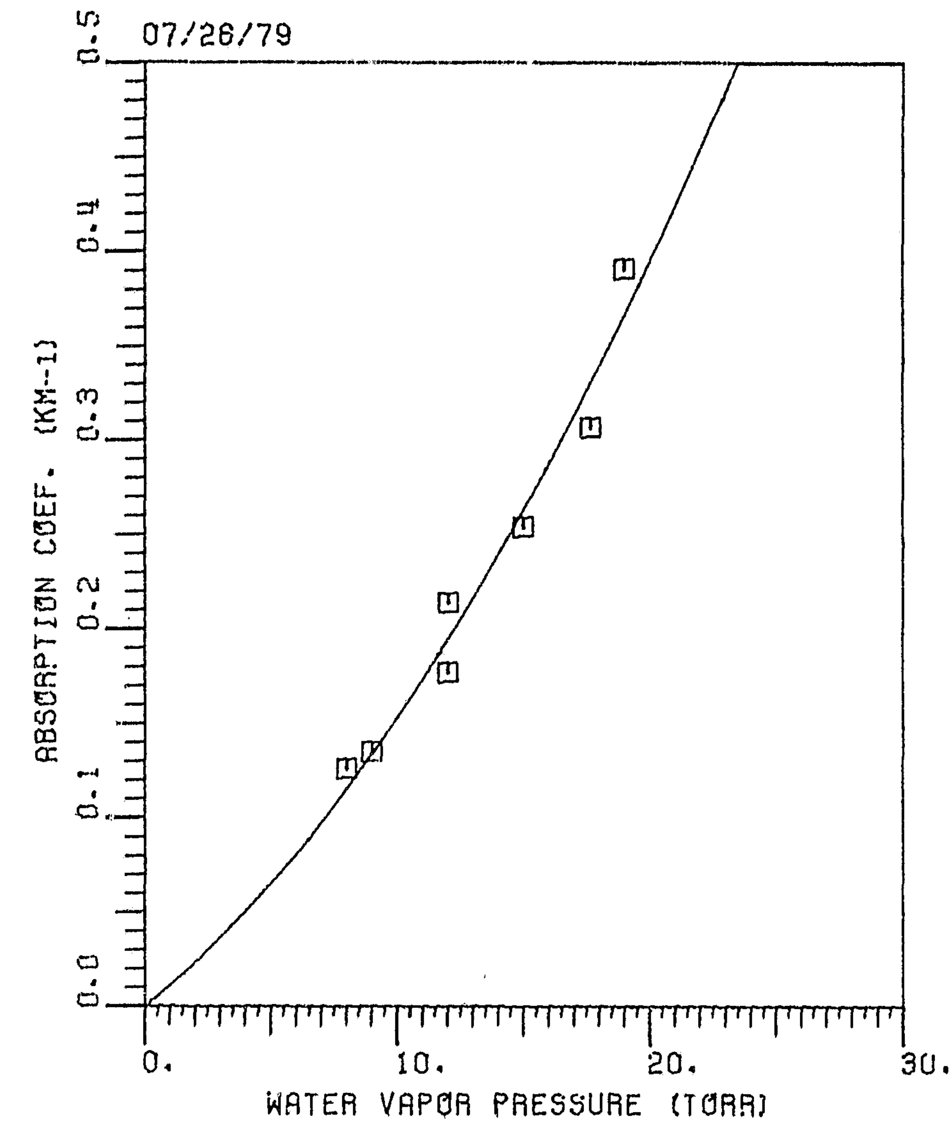

Figure 12. Absorption coefficient vs H_2O partial pressure for P(16) CO_2 laser line at 1050.441 cm^{-1} at 25°C.

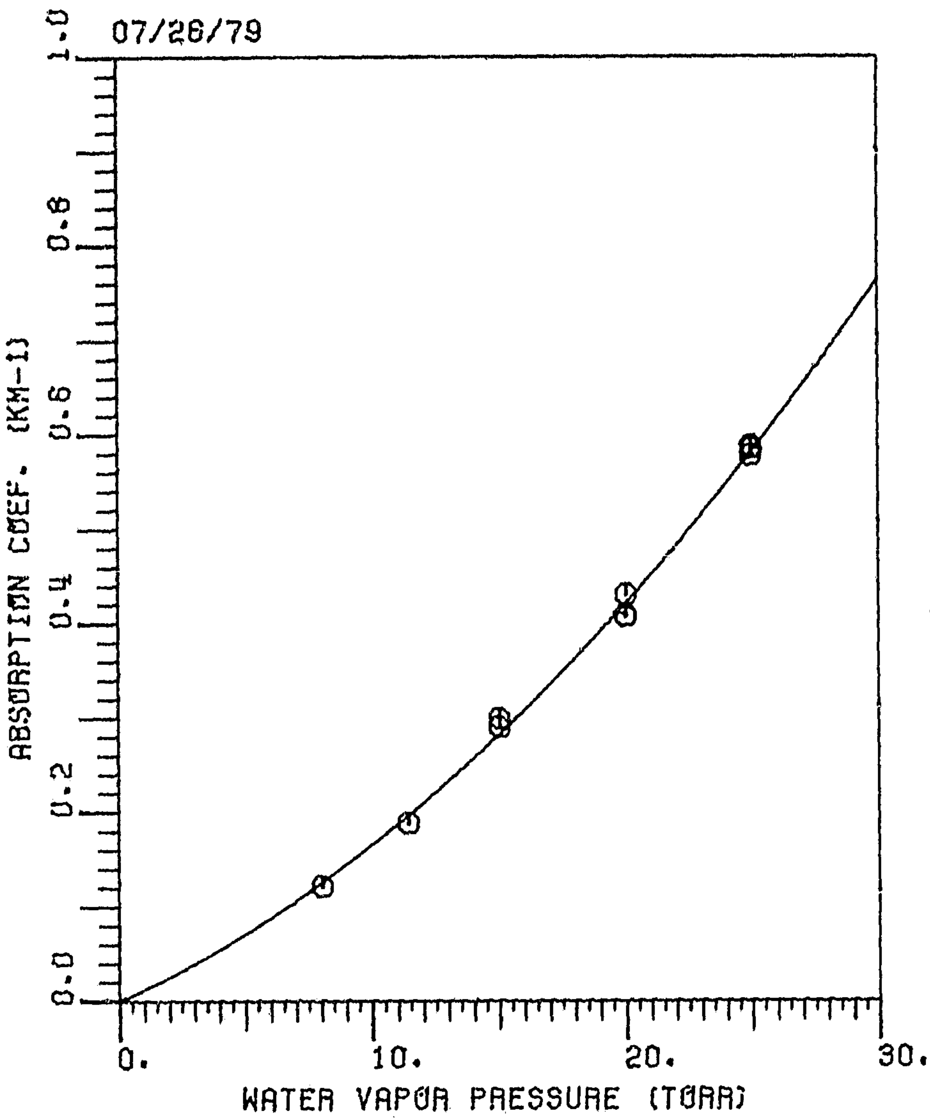

Figure 13. Absorption coefficient vs H_2O partial pressure for P(16) CO_2 laser line at 1050.441 cm^{-1} at 30°C.

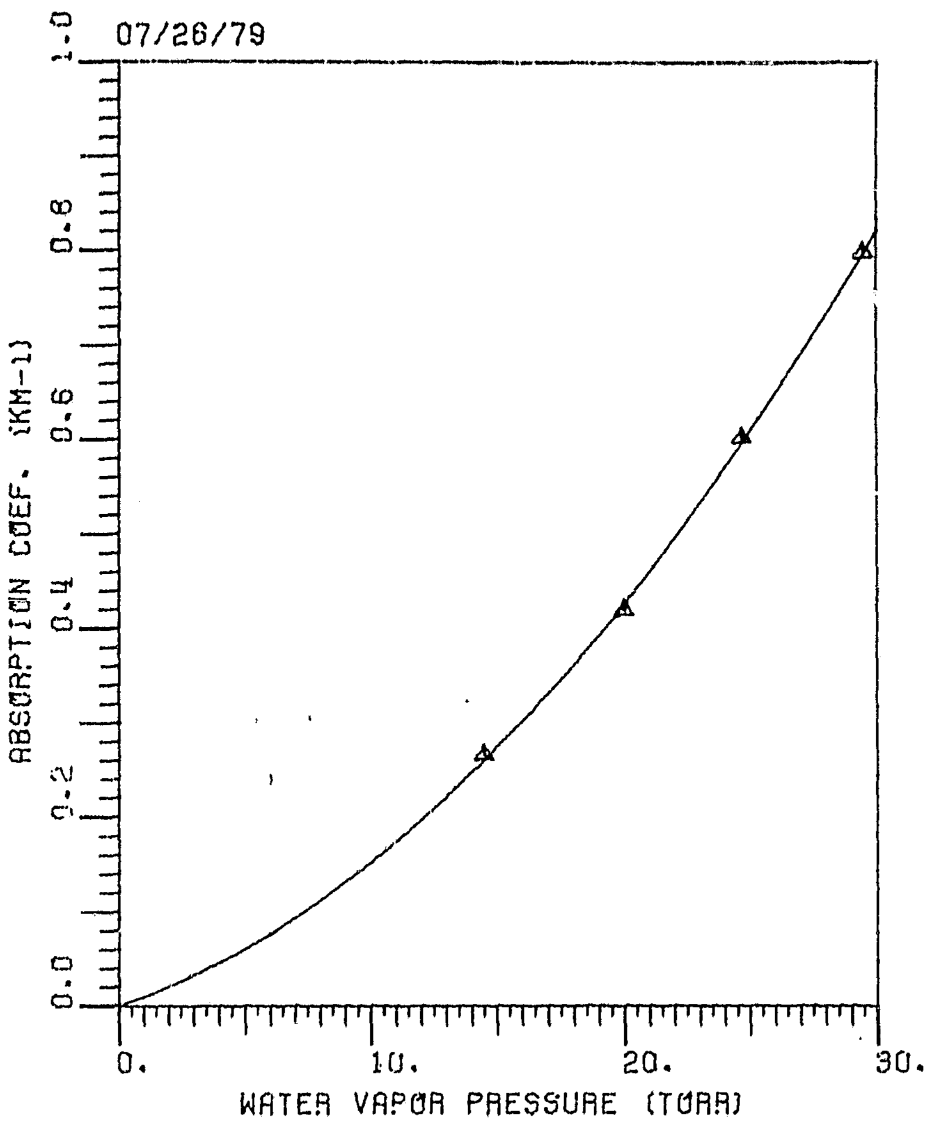

Figure 14. Absorption coefficient vs H_2O partial pressure for P(16) CO_2 laser line at 1050.441 cm^{-1} at 35°C.

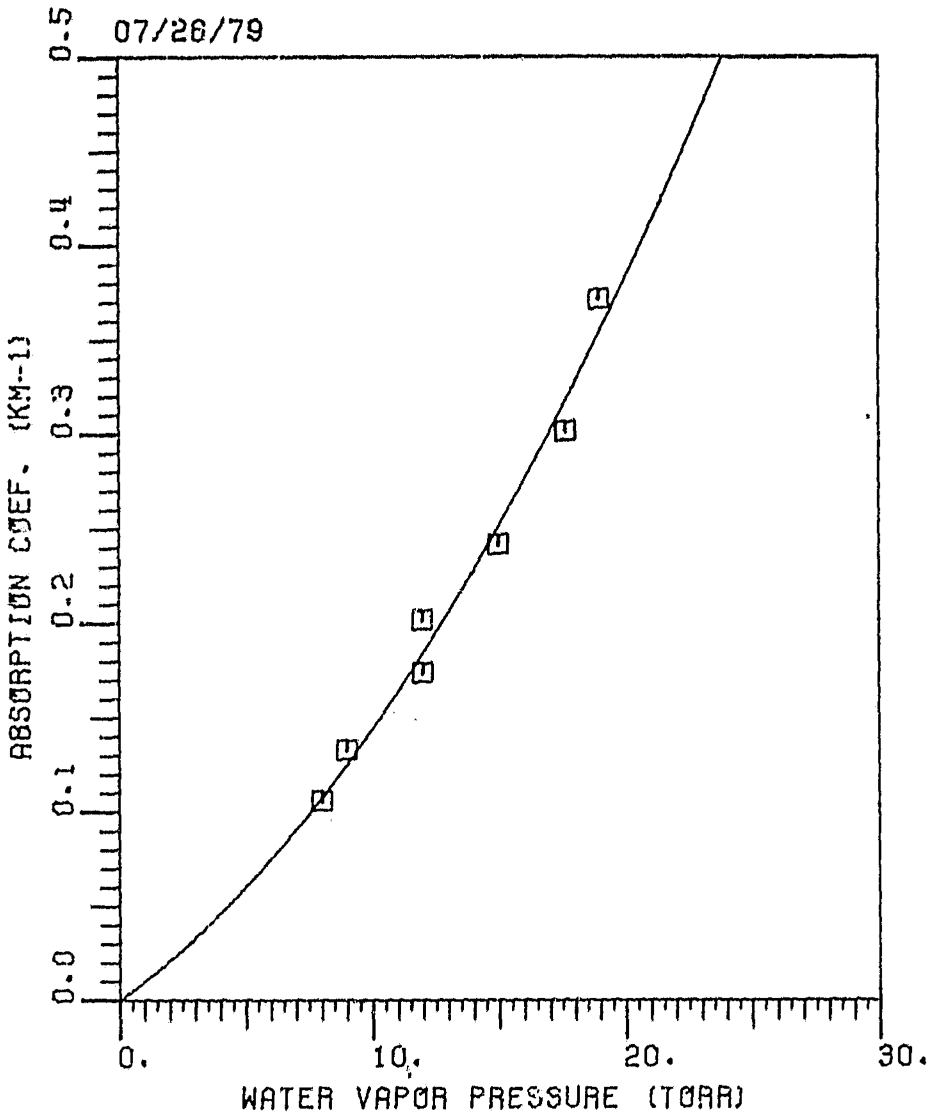

Figure 15. Absorption coefficient vs H_2O partial pressure for P(18) CO_2 laser line at 1048.661 cm^{-1} at 25°C.

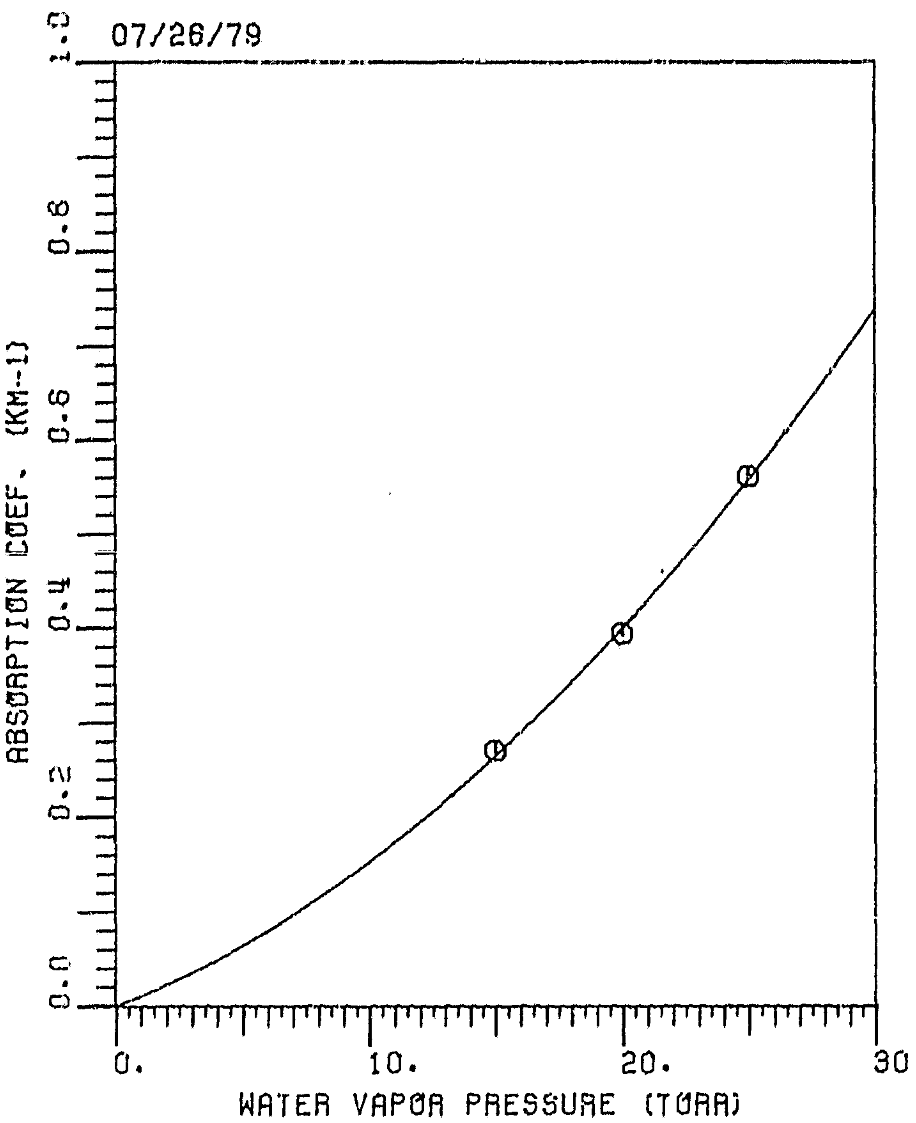

Figure 16. Absorption coefficient vs H_2O partial pressure for P(18) CO_2 laser line at 1048.661 cm^{-1} at 30°C.

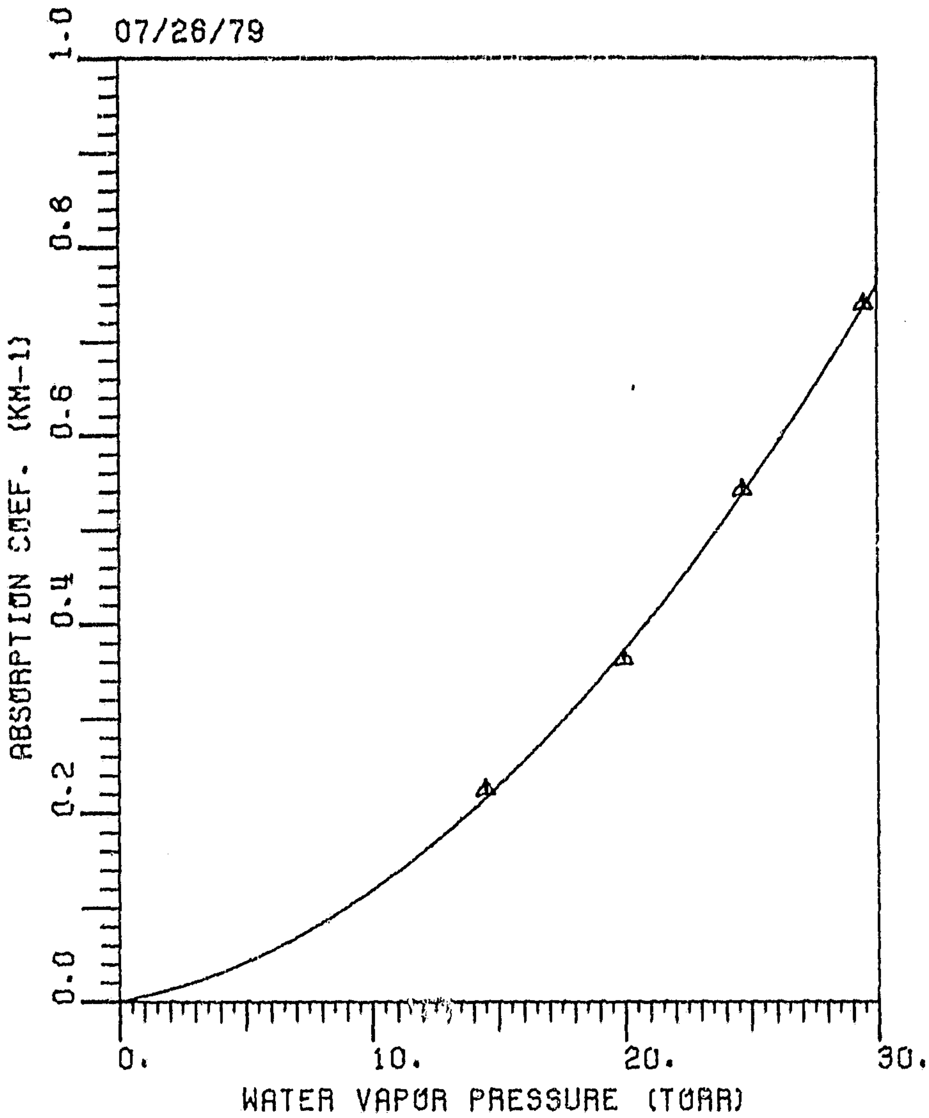

Figure 17. Absorption coefficient vs H_2O partial pressure for P(18) CO_2 laser line at 1048.661 cm^{-1} at 35°C.

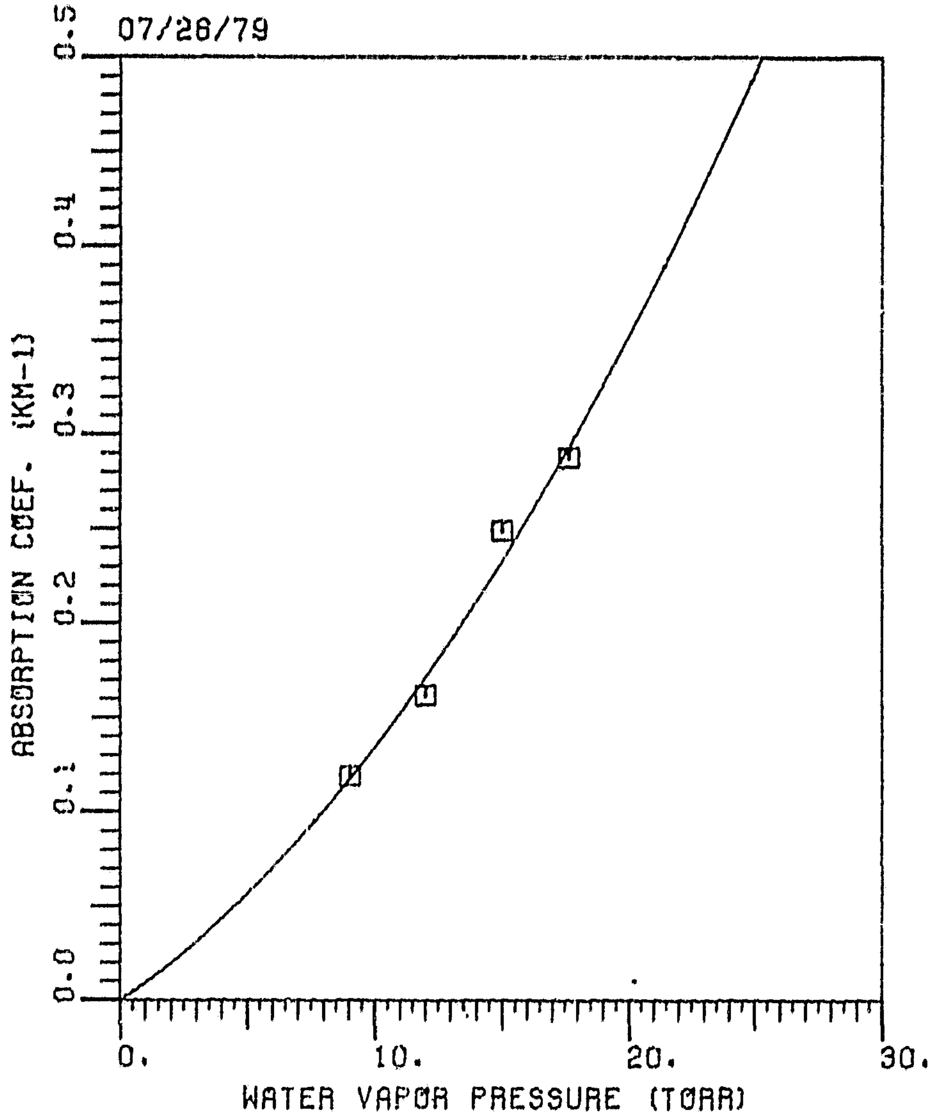

Figure 18. Absorption coefficient vs H_2O partial pressure for P(20) CO_2 laser line at 1046.854 cm^{-1} at 25°C.

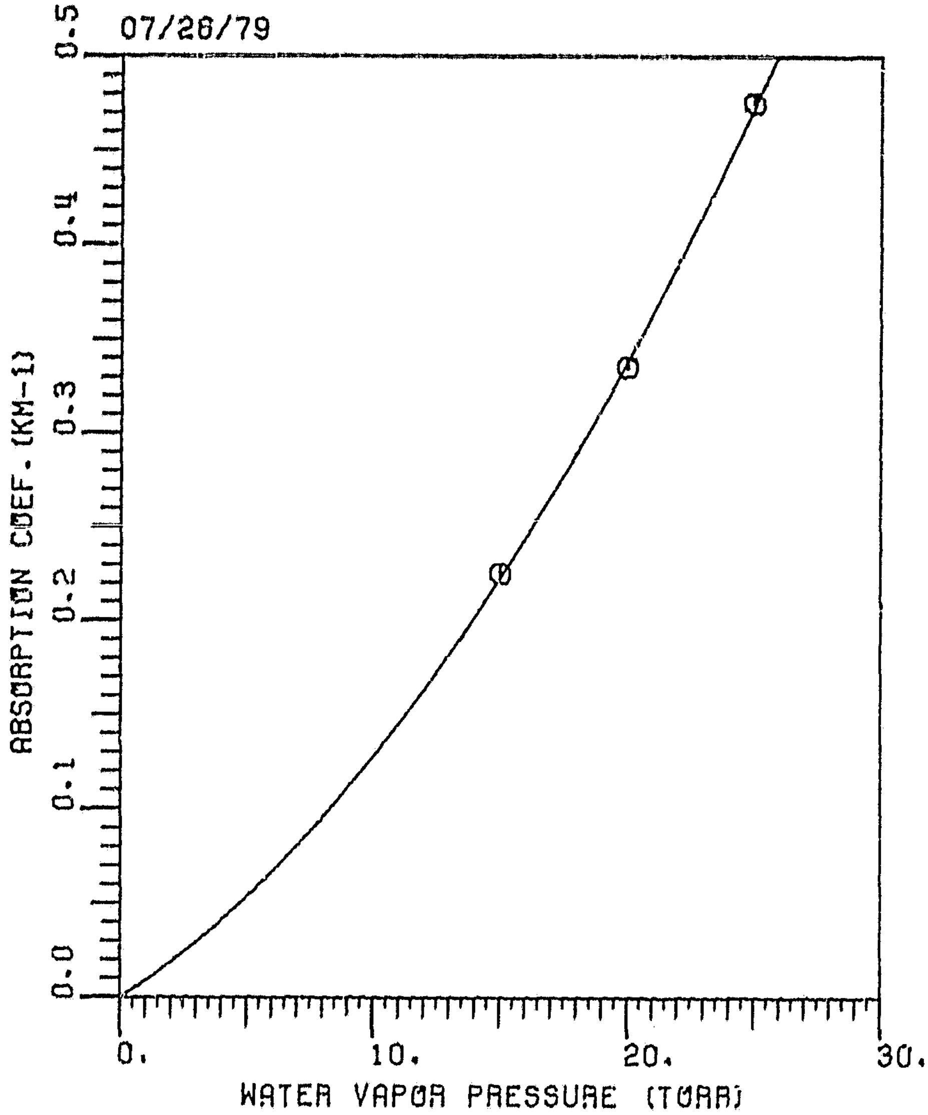

Figure 19. Absorption coefficient vs H_2O partial pressure for P(20) CO_2 laser line at 1046.854 cm^{-1} at 30°C.

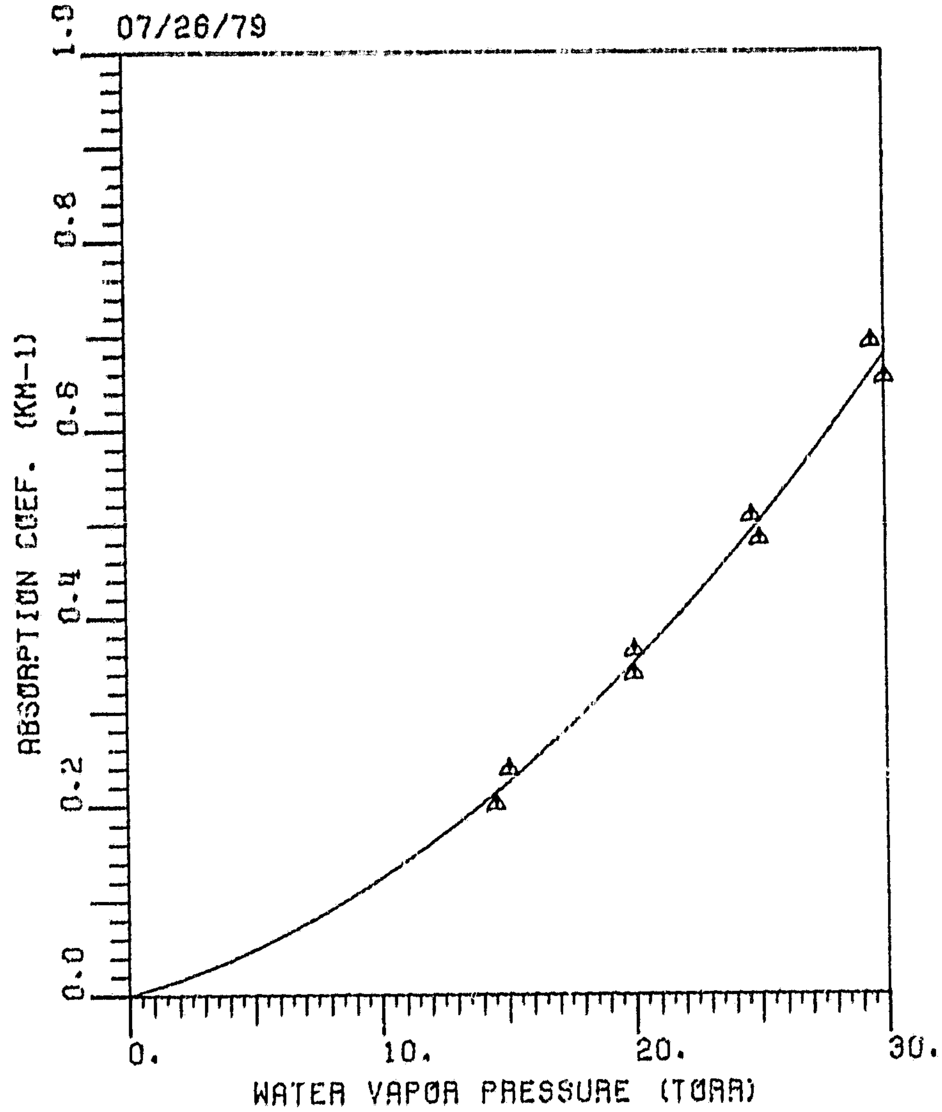

Figure 20. Absorption coefficient vs H_2O partial pressure for P(20) CO_2 laser line at 1046.854 cm^{-1} at 35°C.

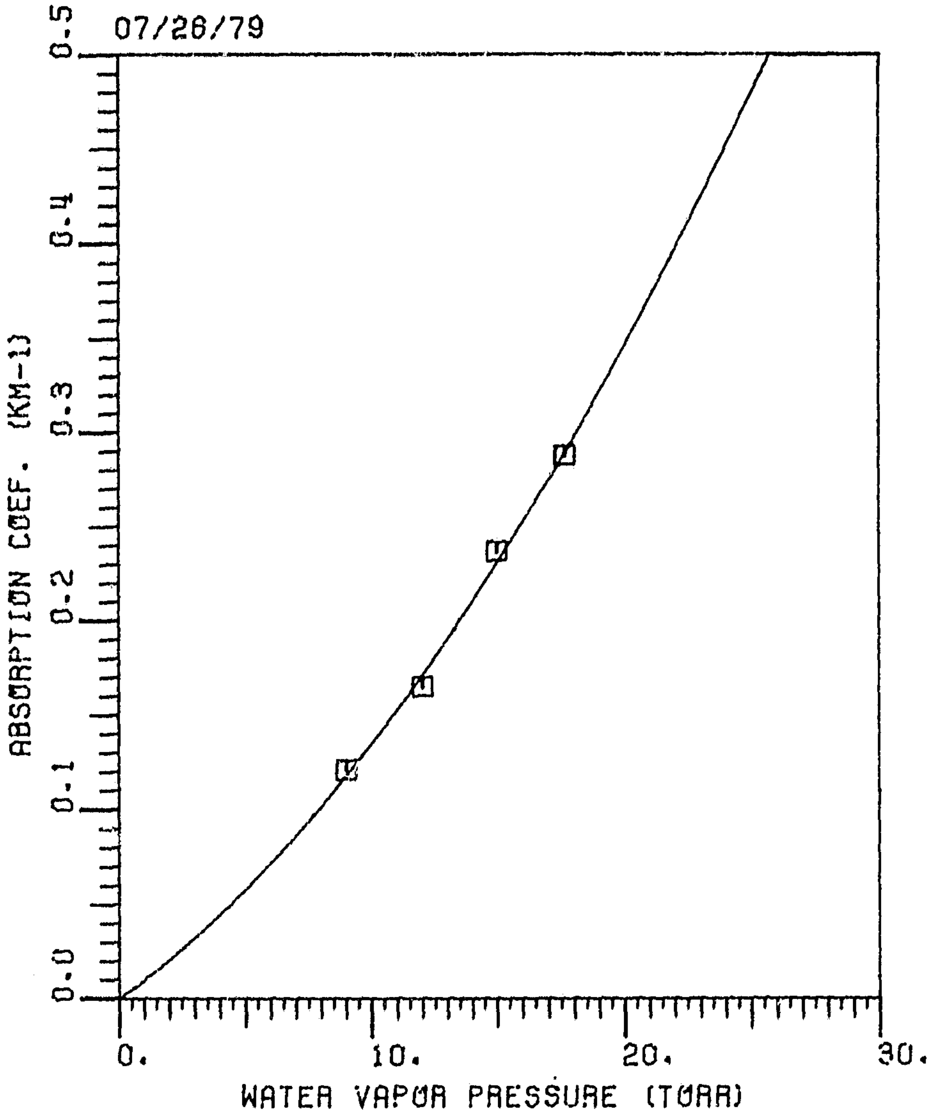

Figure 21. Absorption coefficient vs H_2O partial pressure for P(22) CO_2 laser line at 1045.022 cm^{-1} at 25°C.

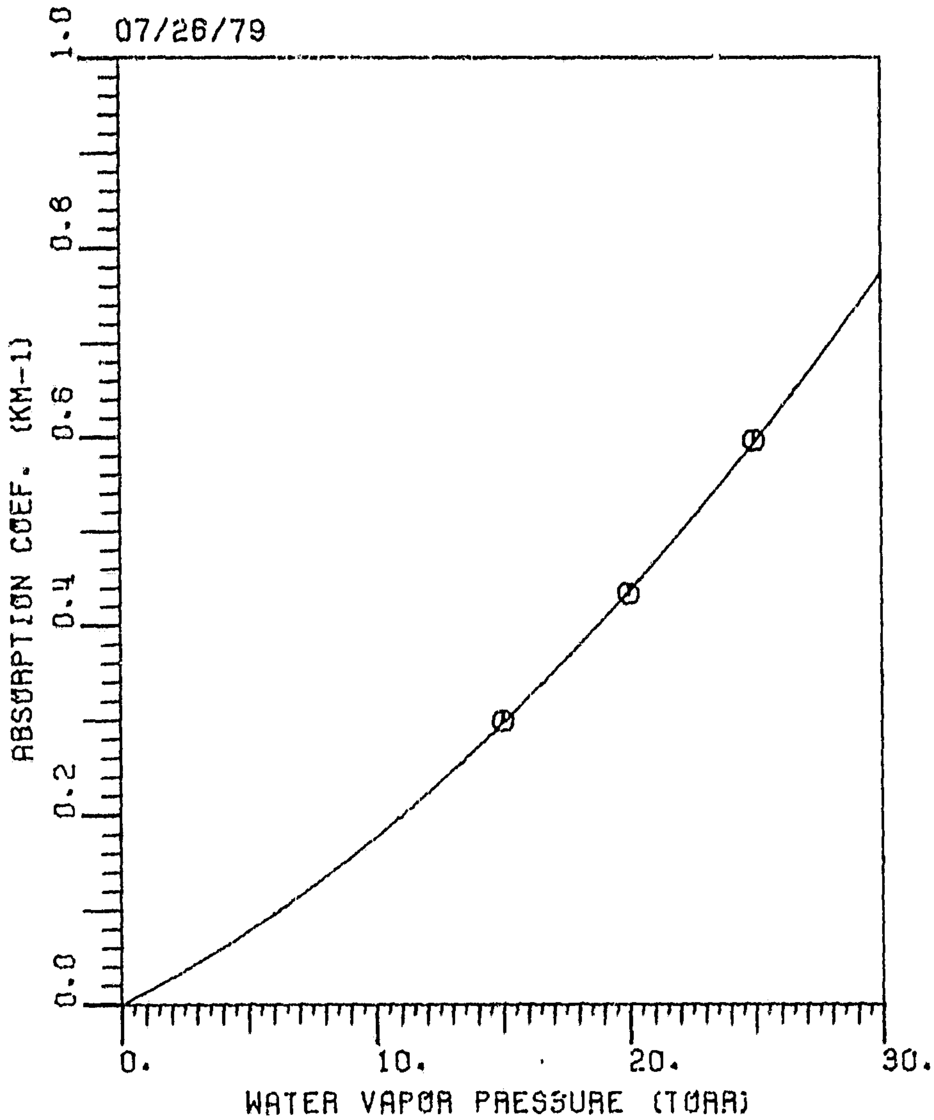

Figure 22. Absorption coefficient vs H_2O partial pressure for P(22) CO_2 laser line at 1045.022 cm^{-1} at 30°C.

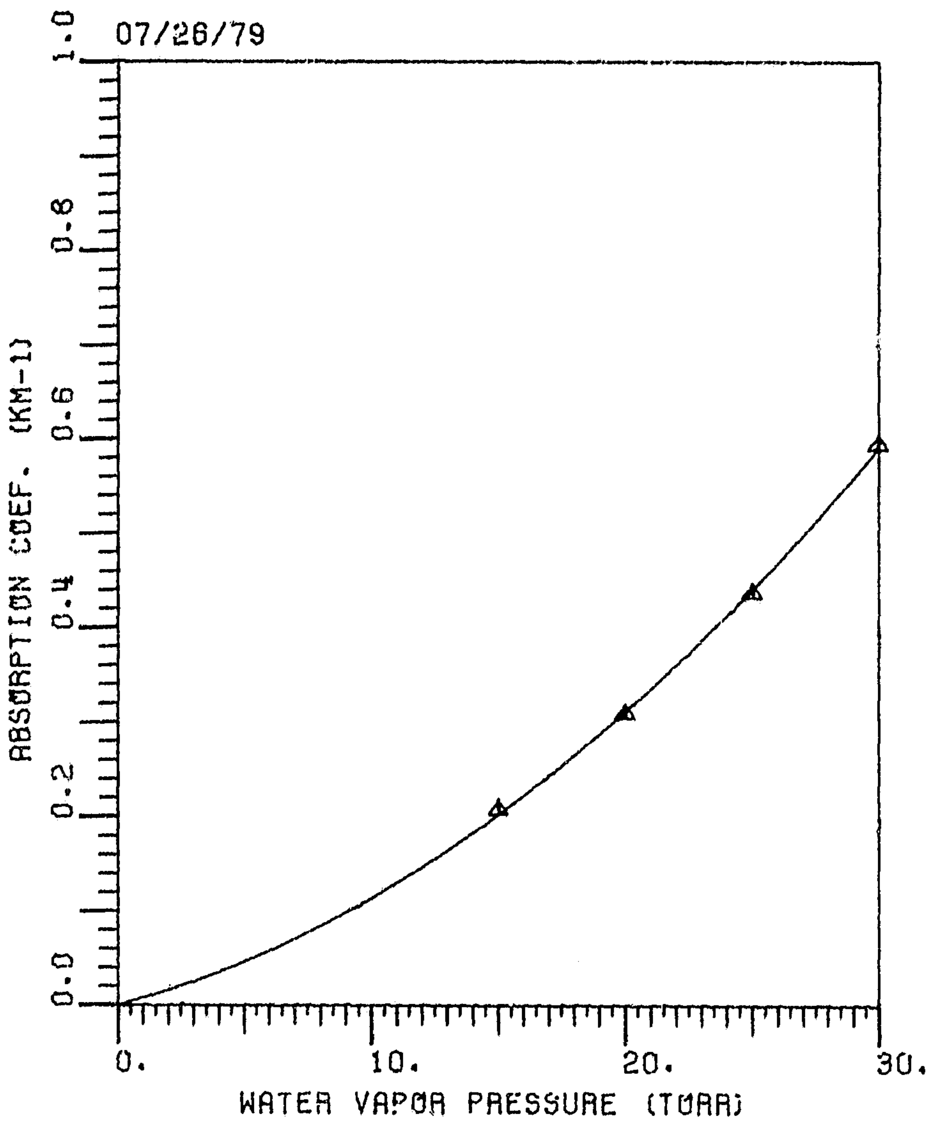

Figure 23. Absorption coefficient vs H_2O partial pressure for P(22) CO_2 laser line at 1045.022 cm^{-1} at 35°C.

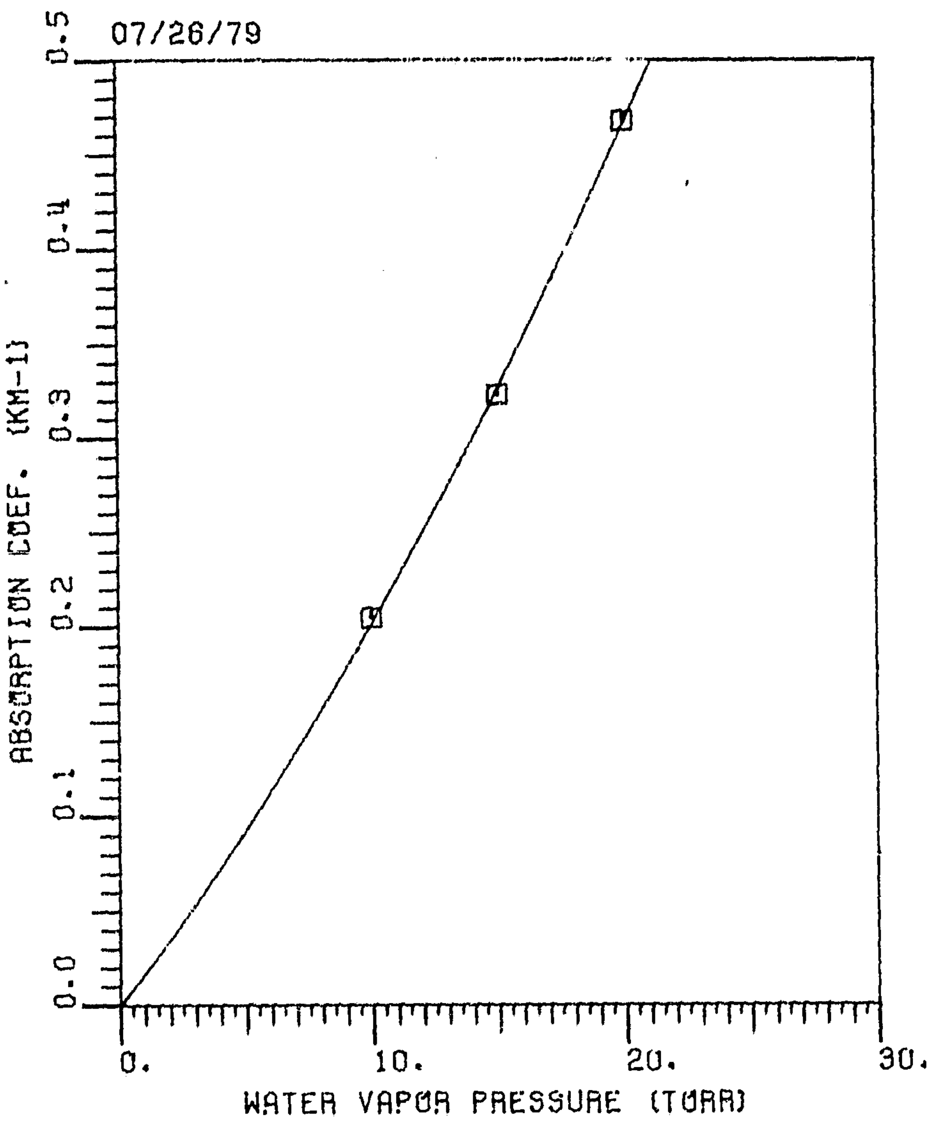

Figure 24. Absorption coefficient vs H_2O partial pressure for P(24) CO_2 laser line at 1043.163 cm^{-1} at 25°C.

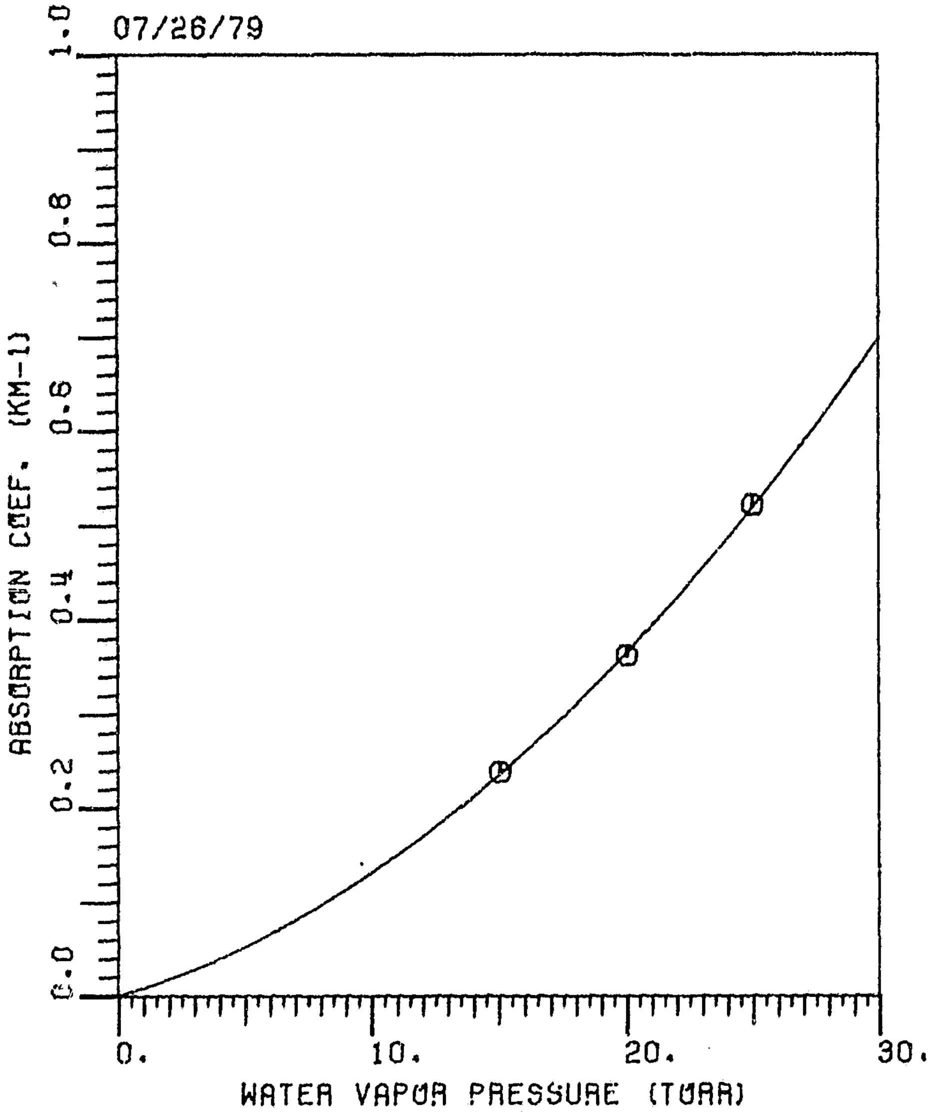

Figure 25. Absorption coefficient vs H_2O partial pressure for P(24) CO_2 laser line at 1043.163 cm^{-1} at 30°C.

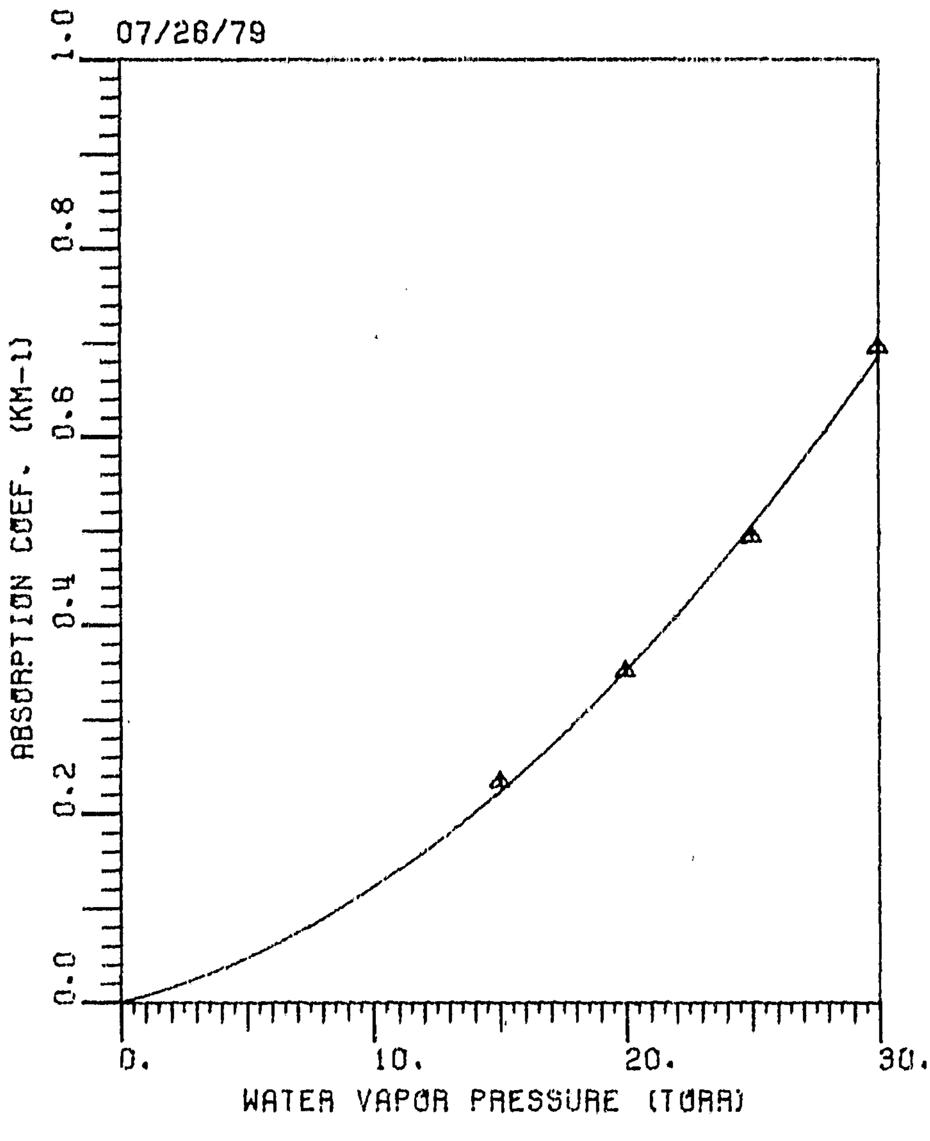

Figure 26. Absorption coefficient vs H_2O partial pressure for P(24) CO_2 laser line at 1043.163 cm^{-1} at 35°C.

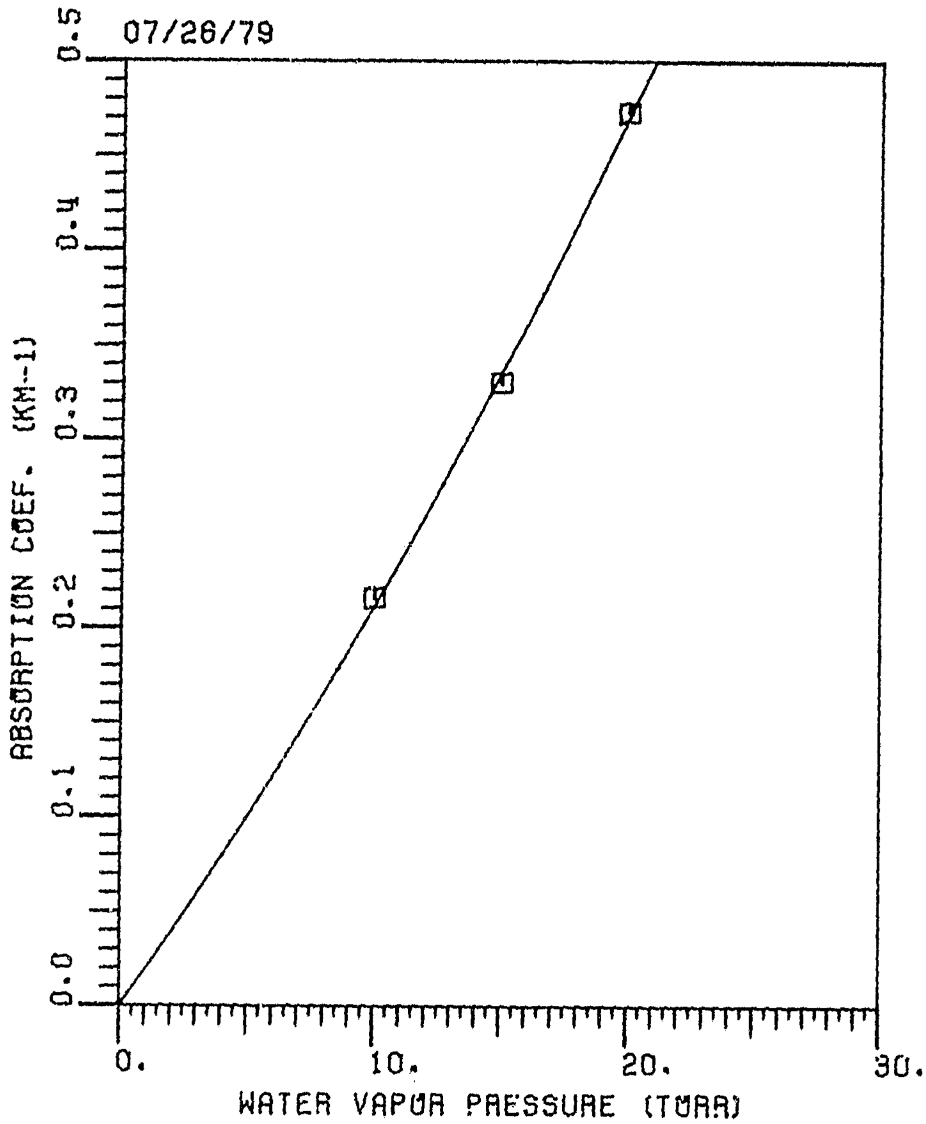

Figure 27. Absorption coefficient vs H_2O partial pressure for P(26) CO_2 laser line at 1041.279 cm^{-1} at 25°C.

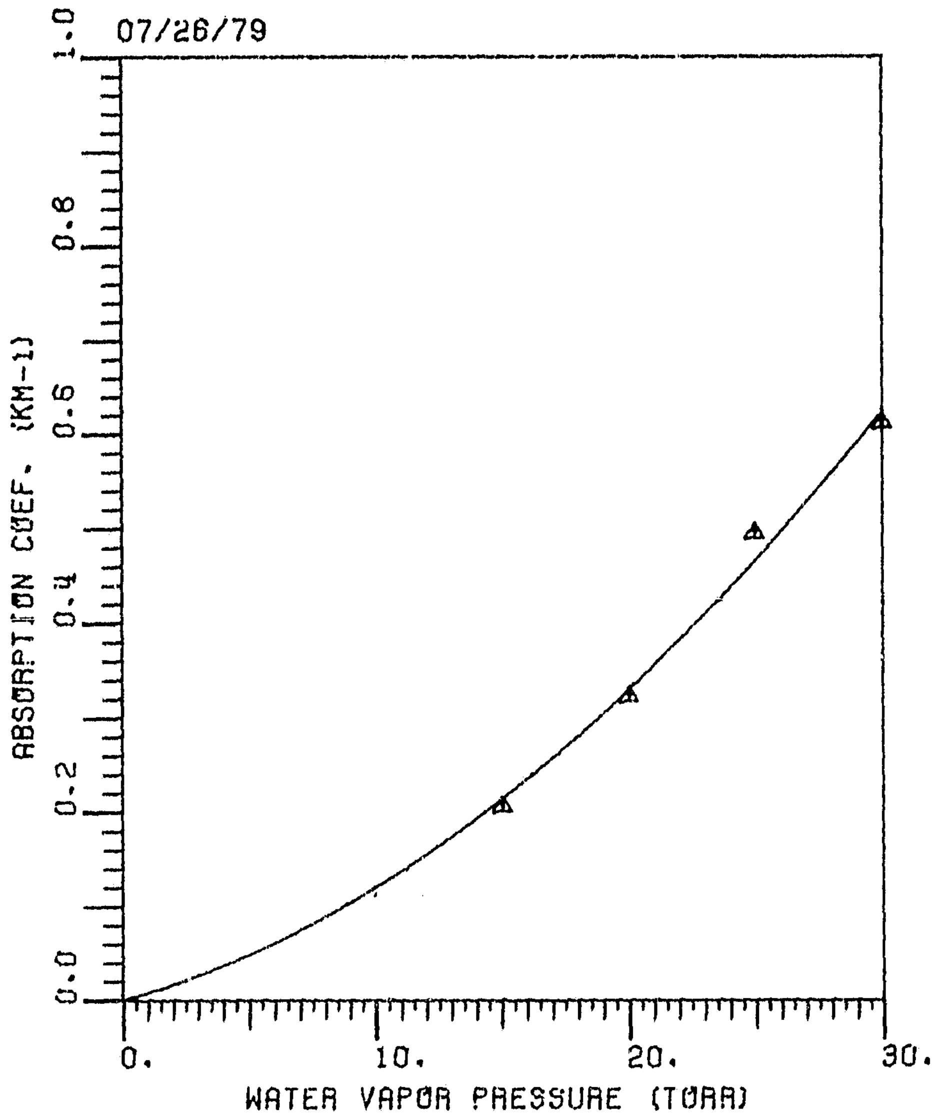

Figure 28. Absorption coefficient vs H_2O partial pressure for P(26) CO_2 laser line at 1041.279 cm^{-1} at 35°C.

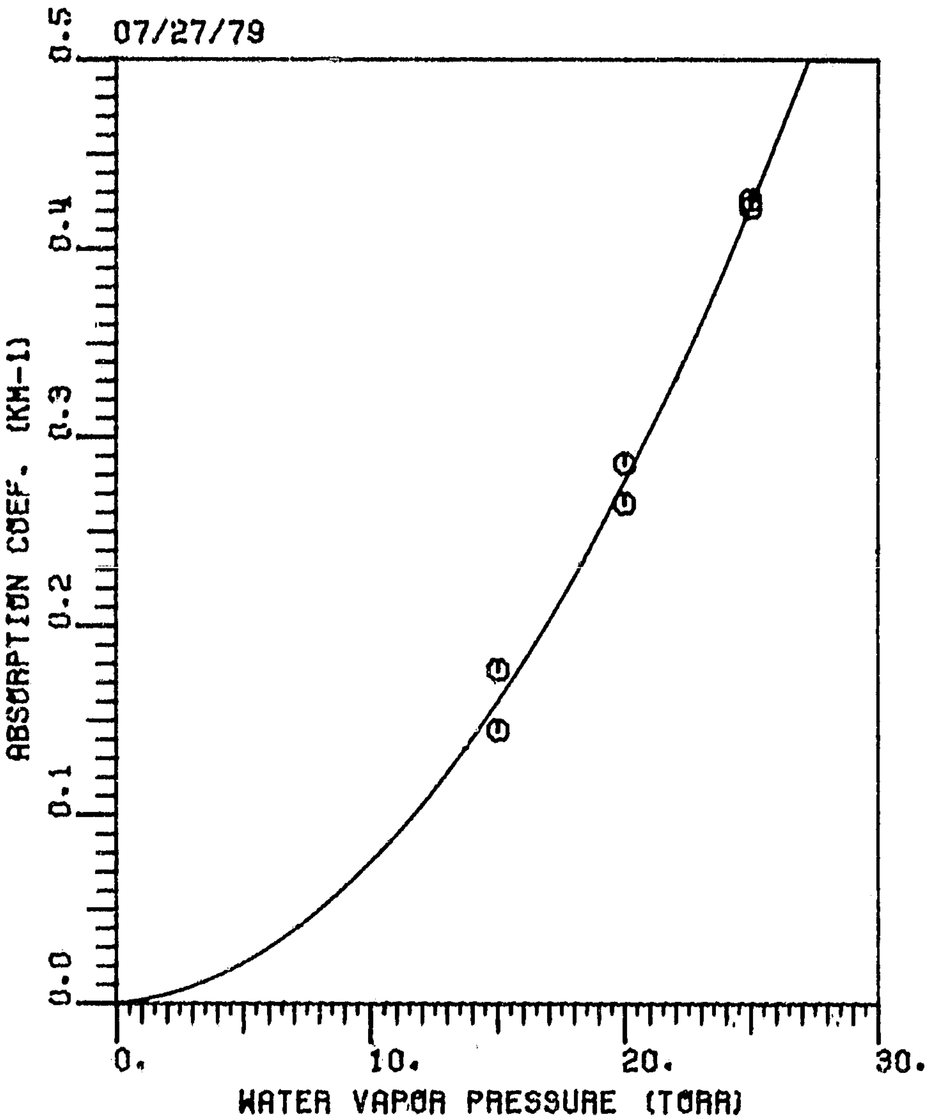

Figure 29. Absorption coefficient vs H_2O partial pressure for R(26) CO_2 laser line at 1082.296 cm^{-1} at 30°C.

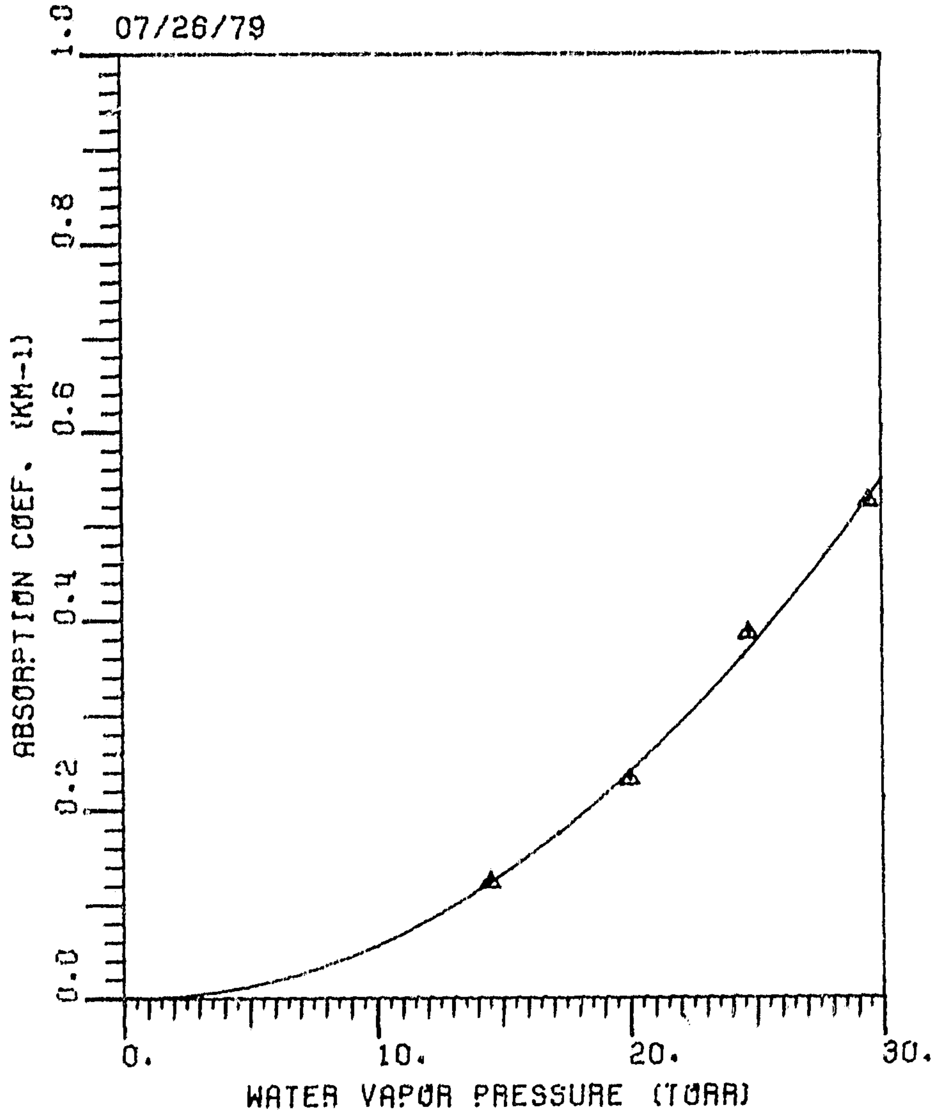

Figure 30. Absorption coefficient vs H_2O partial pressure for R(26) CO_2 laser line at 1082.296 cm^{-1} at 35°C.

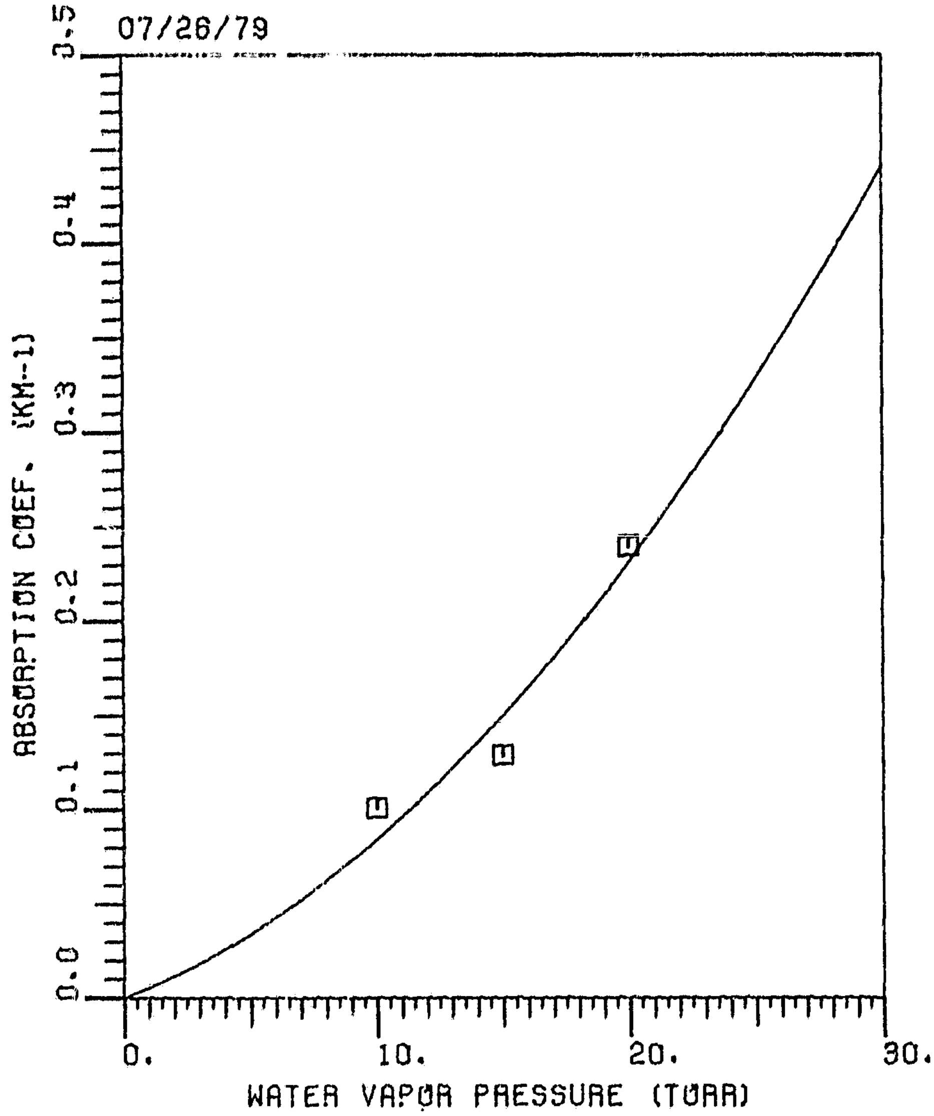

Figure 31. Absorption coefficient vs H_2O partial pressure for R(28) CO_2 laser line at 1083.479 cm^{-1} at 35°C.

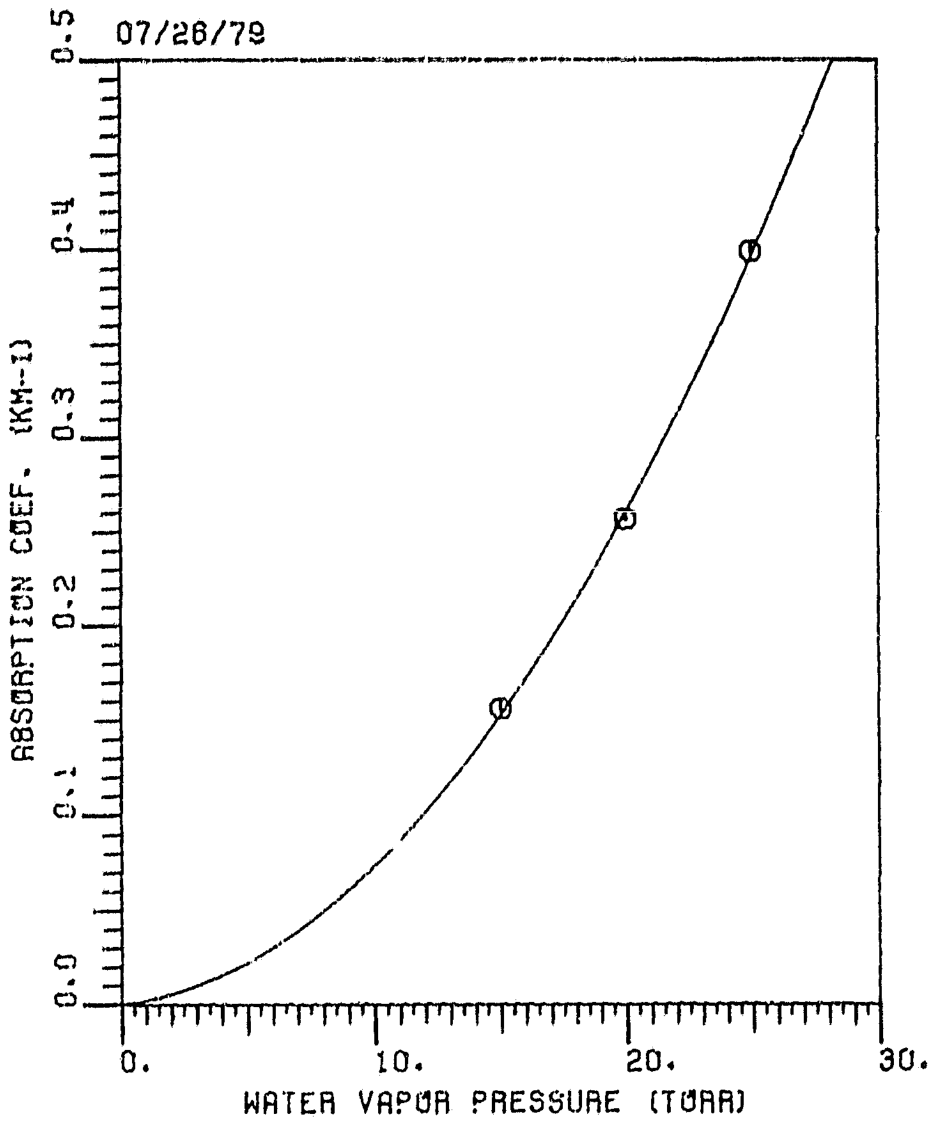

Figure 32. Absorption coefficient vs H_2O partial pressure for R(28) CO_2 laser line at 1083.479 cm^{-1} at 30°C.

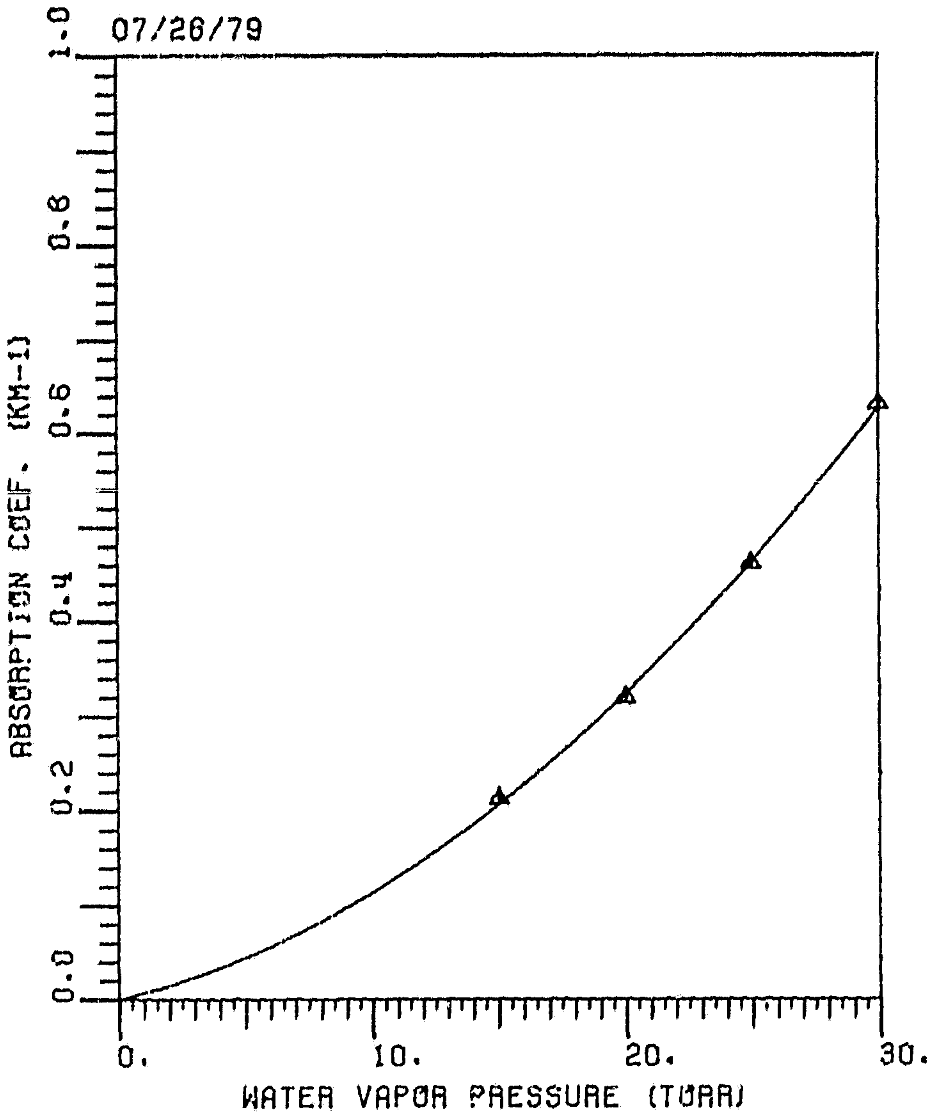

Figure 33. Absorption coefficient vs H_2O partial pressure for R(28) CO_2 laser line at 1083.479 cm^{-1} at 35°C.

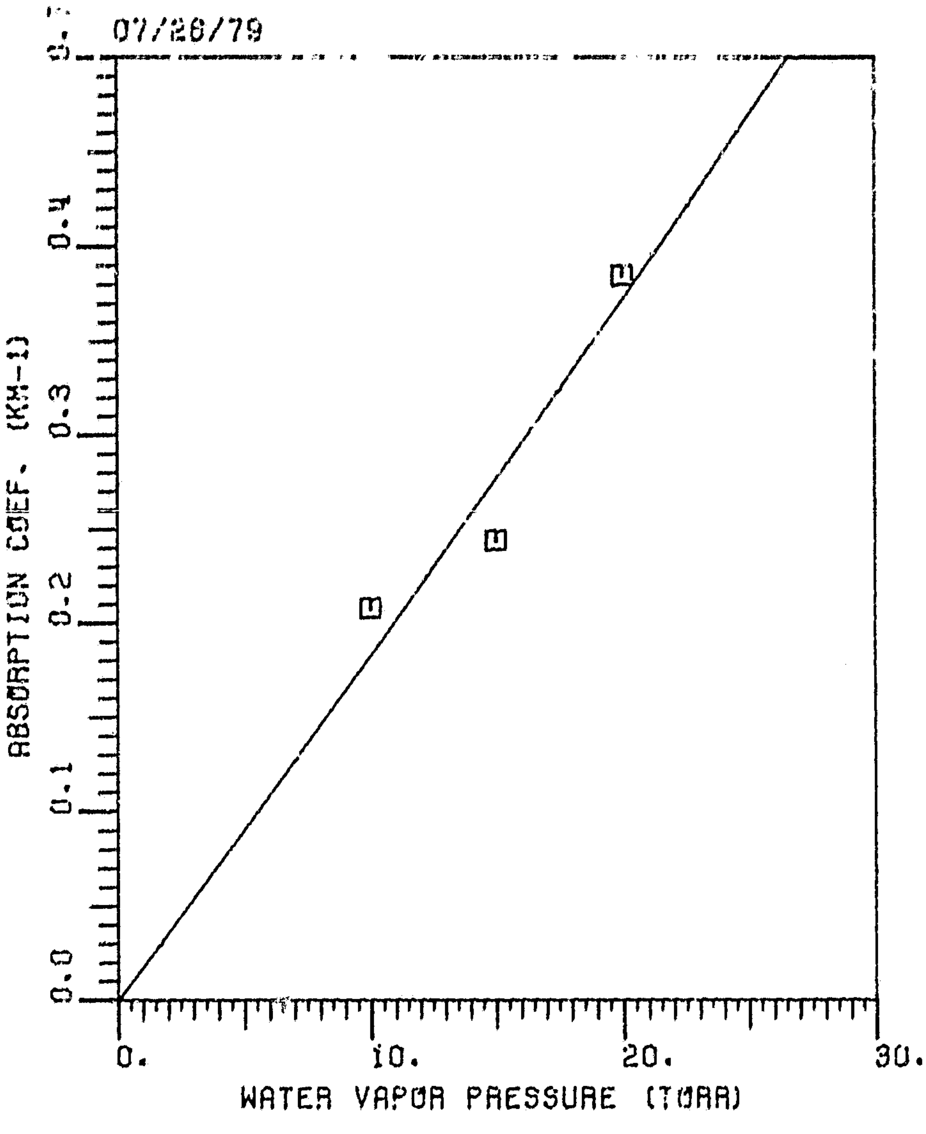

Figure 34. Absorption coefficient vs H_2O partial pressure for R(30) CO_2 laser line at 1084.635 cm^{-1} at 25°C.

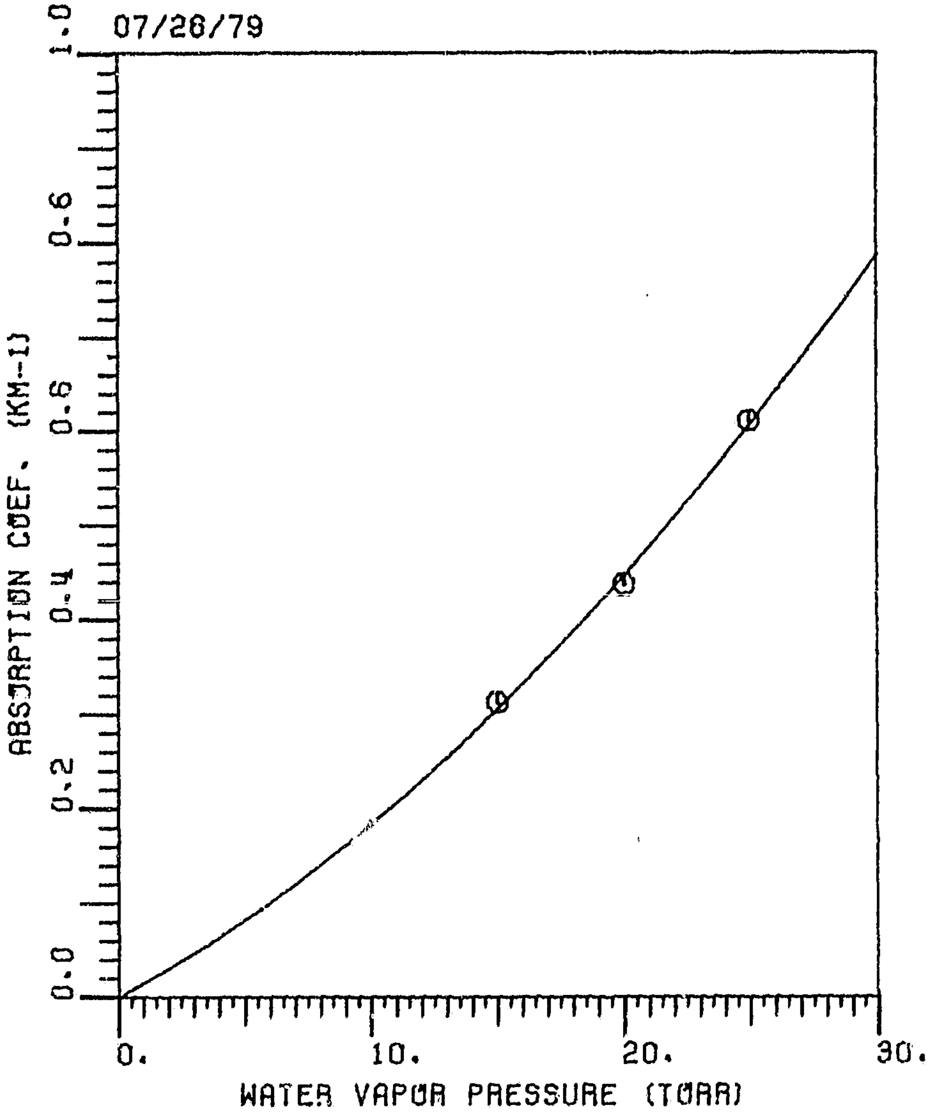

Figure 35. Absorption coefficient vs H_2O partial pressure for R(30) CO_2 laser line at 1084.635 cm^{-1} at 30°C.

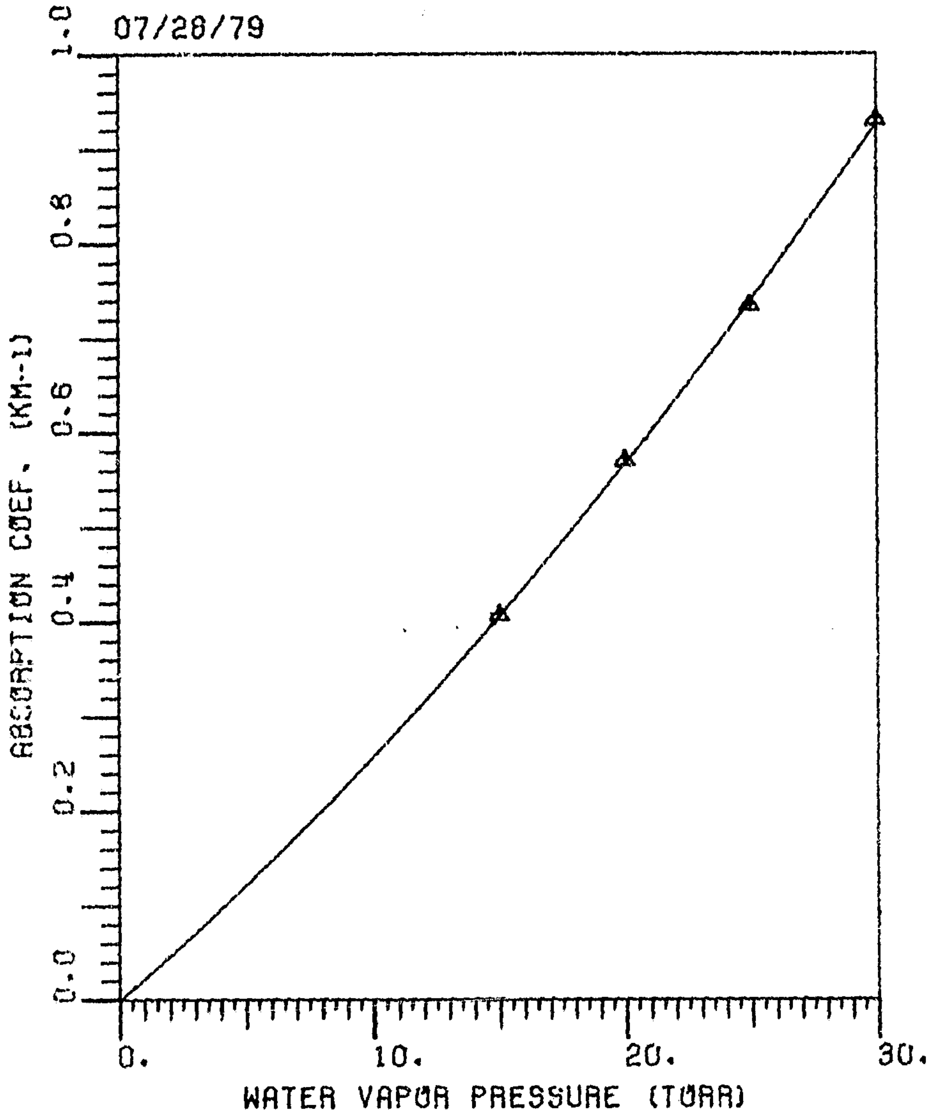

Figure 36. Absorption coefficient vs H_2O partial pressure for R(30) CO_2 laser line at 1084.635 cm^{-1} at 30°C.

Table 2

Listing of curve fit coefficients to the form $k = Ap_a + Bp_a^2$ at three temperatures for 12 CO_2 laser lines.

T = 25°C

	$Ax10^2$	$Bx10^4$	RMS Errorx10^3	Normalized Error
P(10)	2.393	7.701	1.327	.002
P(12)	0.461	8.097	2.046	.007
P(14)	1.076	3.359	6.198	.028
P(16)	1.091	4.430	16.966	.069
P(18)	0.976	4.699	12.777	.054
P(20)	0.939	4.126	9.746	.045
P(22)	0.976	3.767	4.611	.022
P(24)	1.712	3.105	2.765	.008
P(26)	1.883	2.360	4.148	.012
R(26)				
R(28)	0.537	3.114	16.258	.097
R(30)	1.800	0.312	24.940	.086

T = 30°C

	$Ax10^2$	$Bx10^4$	RMS Errorx10^3	Normalized Error
P(10)	3.651	2.560	4.102	.005
P(12)	1.264	4.853	1.367	.003
P(14)	1.362	5.336	21.774	.046
P(16)	1.222	4.426	9.491	.022
P(18)	1.078	4.624	4.740	.011
P(20)	0.873	4.089	2.279	.006
P(22)	1.379	4.020	1.884	.004
P(24)	0.813	5.063	2.309	.006
P(26)				
R(26)	0.132	6.251	11.128	.036
R(28)	0.170	5.677	3.008	.010
R(30)	1.450	3.913	7.019	.015

T = 35°C

	$Ax10^2$	$Bx10^4$	RMS Errorx10^3	Normalized Error
P(10)	3.251	3.768	6.053	.006
P(12)	1.521	2.555	18.383	.036
P(14)	1.537	5.134	6.780	.010
P(16)	0.929	6.024	4.949	.009
P(18)	0.526	6.708	6.690	.013
P(20)	0.733	5.112	19.051	.041
P(22)	0.733	4.134	4.022	.010
P(24)	0.709	5.270	9.145	.019
P(26)	0.775	4.369	16.702	.038
R(26)	-0.062	6.306	9.535	.027
R(28)	0.667	4.756	4.300	.010
R(30)	2.324	2.553	3.957	.006

Table 3

Absorption coefficient listing at three temperatures for 12 CO_2 laser lines. (km^{-1})

Line ID	$T(^oC)$	Partial Pressure of H_2O 15	20	25	30 (Torr)
00^01-02^00 P(10)	25	.532	.787		
@ 1055.625 cm^{-1}	30	.605	.833	1.076	
	35	.572	.735	1.048	1.304
00^01-02^00 P(12)	25	.251	.416		
@ 1053.924 cm^{-1}	30	.299	.447	.619	
	35	.286	.406	.540	.686
00^01-02^00 P(14)	25	.237	.350		
@ 1052.196 cm^{-1}	30	.324	.486	.674	
	35	.346	.513	.705	.923
00^01-02^00 P(16)	25	.263	.395		
@ 1050.441 cm^{-1}	30	.283	.421	.582	
	35	.275	.427	.609	.821
00^01-02^00 P(18)	25	.255	.383		
@ 1048.661 cm^{-1}	30	.266	.401	.559	
	35	.230	.373	.551	.762
00^01-02^00 P(20)	25	.234	.353		
@ 1046.854 cm^{-1}	30	.223	.338	.474	
	35	.225	.351	.503	.680
00^01-02^0C P(22)	25	.231	.346		
@ 1045.022 cm^{-1}	30	.297	.437	.596	
	35	.203	.311	.442	.592
00^01-02^0C P(24)	25	.327	.467		
@ 1043.163 cm^{-1}	30	.236	.365	.520	
	35	.225	.353	.507	.687
00^01-02^0C P(26)	25	.336	.471		
@ 1041.279 cm^{-1}	30				
	35	.215	.330	.467	.626
00^01-02^0C R(26)	25				
@ 1082.296 cm^{-1}	30	.160	.276	.424	
	35	.133	.240	.379	.550
00^01-02^0C R(28)	25	.151	.252		
@ 1083.479 cm^{-1}	30	.153	.261	.397	
	35	.207	.324	.464	.628
00^01-02^0C R(30)	25	.277	.373		
@ 1084.635 cm^{-1}	30	.306	.447	.607	
	35	.406	.566	.739	.925

APPENDIX A

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: P(10)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	0.737	1.873	0.393	0.786	25.1±0.2
15	17.6	0.994	1.873	0.531	0.534	25.1
10	11.7	1.289	1.873	0.688	0.315	25.1
BKG		1.873				

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/5/79

Laser line ID: P(10)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.8	0.606	2.170	0.279	1.075	30.2±0.2
20	22.0	0.814	2.170	0.375	0.827	30.2
15	17.6	1.053	2.170	0.485	0.609	30.2
BKG		2.170				

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/26/79

Laser line ID: P(10)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	0.680	3.253	0.209	1.319	34.8 ± 0.3
25	25.4	0.947	3.253	0.209	1.040	34.8
20	22					34.8
15	17.5	1.641	3.253	0.504	0.577	34.8
BKG		3.253				34.8

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: P(12)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	1.162	1.901	0.611	0.415	25.1 ± 0.2
15	17.6	1.407	1.901	0.740	0.254	25.1
10	11.7	1.639	1.901	0.862	0.125	25.1
BKG		1.901				25.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/5/79

Laser line ID: P(12)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.8	1.057	2.205	0.479	0.620	30.2±0.2
20	22.0	1.300	2.205	0.590	0.445	30.2
15	17.6	1.555	2.205	0.700	0.300	30.2
BKG		2.205				30.2

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/26/79

Laser line ID: P(12)

Sample Gas: H_2O in Air

Cell path length: 0.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	1.469	3.297	0.446	0.681	34.8±0.3
25	25.4	1.742	3.297	0.528	0.538	34.8
20	22	1.970	3.297	0.598	0.434	34.8
15	17.5	2.415	3.297	0.732	0.262	34.8
BKG		3.297				34.8

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 5/18/79

Laser line ID: P(14)

Sample Gas: H_2O in Air

Cell path length: 1.35891

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
17.66	20	1.221	1.808	0.675	0.289	25.2±0.2
15	17.6	1.295	1.808	0.716	0.246	25.2
12	14.3	1.418	1.808	0.784	0.179	25.2
9	10.2	1.540	1.808	0.852	0.118	25.2
BKG		1.808				25.2

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/8/79 and 5/31/79

Laser line ID: P(14)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.093	2.349	0.465	0.645	30.2±0.2
20	22.0	1.367	2.349	0.582	0.456	30.2
15	17.8	1.596	2.349	0.680	0.326	30.2
BKG		2.349				30.2
25	25.6	1.013	2.350	0.431	0.709	30.0±0.2
20	22	1.292	2.350	0.550	0.504	30.0
11.4	13.6	1.788	2.350	0.761	0.230	30.0
8	8.9	1.980	2.350	0.843	0.144	30.0
BKG		2.350				30.0

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/21/79

Laser line ID: P(14)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
29.5	28.5	0.699	2.042	0.342	0.904	35.0$\pm$0.3
24.7	25.4	0.900	2.042	0.441	0.690	35.0
20	22.1	1.124	2.042	0.550	0.504	35.0
14.5	17.2	1.364	2.042	0.668	0.340	35.0
BKG		2,042				35.0

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 5/18/79 and 5/25/79

Laser line ID: P(16)

Sample Gas: H_2O in Air

Cell path length: 1.35891

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
17.66	20	1.235	1.875	0.659	0.307	25.2±.2
15	17.6	1.328	1.875	0.708	0.254	25.2
12	14.3	1.474	1.875	0.786	0.177	25.2
9	10.2	1.560	1.875	0.832	0.135	25.2
BKG		1.875				25.2
19	20	1.124	1.913	0.588	0.391	25.0±0.2
12	14.6	1.430	1.913	0.748	0.214	25.0
8	8.7	1.613	1.913	0.843	0.125	25.0
BKG		1.913				25.0

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 5/31/79 and 6/8/79

Laser line ID: P(16)

Sample Gas: H_2O in Air

Cell path length: 1.35891 and 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	0.763	1.675	0.455	0.578	30.0 ± 0.2
20	22	0.961	1.675	0.573	0.408	30.0
11.4	13.6	1.296	1.675	0.773	0.189	30.0
8	8.9	1.420	1.675	0.848	0.122	30.0
BKG		1.675				30.0
25	25.6	1.176	2.355	0.499	0.585	30.2 ± 0.2
20	22	1.451	2.355	0.616	0.408	30.2
15	17.8	1.669	2.355	0.709	0.290	30.2
BKG		2.355				30.2

$$-\frac{\ell n\ T}{\ell} = k$$

Comments: Continued next sheet

DATA ANALYSIS SHEET

Date: 7/6/79

Laser line ID: P(16)

Sample Gas: H_2O in Air

Cell path length: 1.18

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.004	2.018	0.498	0.588	30.1±0.2
20	22.0	1.210	2.018	0.600	0.431	30.1
15	17.6	1.415	2.018	0.701	0.299	30.1
BKG		2.018				30.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/21/79

Laser line ID: P(16)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
29.5	28.5	0.810	2.0867	0.388	0.798	35.0±0.3
24.7	25.4	1.023	2.0867	0.490	0.601	35.0
20	22.1	1.268	2.0867	0.608	0.419	35.0
14.5	17.2	1.522	2.0867	0.729	0.266	35.0
BKG		2.0867				35.0

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 5/18/79 and 5/25/79

Laser line ID: P(18)

Sample Gas: H_2O in Air

Cell path length: 1.35891

Experiment performed by: ________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
17.66	20	1.227	1.849	0.664	0.302	25.2±0.2
15	17.6	1.330	1.849	0.719	0.242	25.2
12	14.3	1.460	1.849	0.790	0.174	25.2
9	10.2	1.544	1.849	0.835	0.133	25.2
BKG		1.849				25.2
19	20	1.146	1.901	0.603	0.372	25.0±0.2
12	14.6	1.444	1.901	0.760	0.202	25.0
8	8.7	1.646	1.901	0.866	0.106	25.0
BKG		1.901				25.0

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/8/79

Laser line ID: P(18)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.162	2.260	0.514	0.561	30.0±0.2
20	22.0	1.416	2.260	0.626	0.394	30.0
15	17.8	1.640	2.260	0.726	0.270	30.0
BKG		2.260				30.0

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/21/79 .

Laser line ID: P(18)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
29.5	28.5	0.868	2.0876	0.416	0.740	35.0±0.3
24.7	25.4	1.098	2.0876	0.526	0.542	35.0
20	22.1	1.357	2.0876	0.650	0.363	35.0
14.5	17.2	1.599	2.0876	0.766	0.225	35.0
BKG		2.0876				35.0

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 5/18/79

Laser line ID: P(20)

Sample Gas: H_2O in Air

Cell path length: 1.35891

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
17.66	20	1.327	1.963	0.676	0.288	25.2 ± 0.2
15	17.6	1.400	1.963	0.713	0.249	25.2
12	14.3	1.575	1.963	0.802	0.162	25.2
9	10.2	1.67	1.963	0.851	0.119	25.2
BKG		1.963				25.2

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/6/79

Laser line ID: P(20)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.151	2.022	0.569	0.475	30.1 ± 0.2
20	22.0	1.359	2.022	0.672	0.335	30.1
15	17.6	1.548	2.022	0.766	0.225	30.1
BKG		2.022				30.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/21/79 and 6/26/79

Laser line ID: P(20)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
29.5	28.5	1.072	2.434	0.440	0.692	35.0±0.3
24.7	25.4	1.335	2.434	0.548	0.507	35.0
20	22.1	1.630	2.434	0.669	0.339	35.0
14.5	17.2	1.917	2.434	0.788	0.201	35.0
BKG		2.434				35.0
30	28.6	1.580	3.437	0.460	0.654	34.8±0.3
25	25.4	1.939	3.437	0.564	0.482	34.8
20	22	2.231	3.437	0.645	0.364	34.8
15	17.5	2.595	3.437	0.755	0.238	34.8
BKG		3.437				34.8

$-\frac{\ln T}{\ell} = k$

Comments:

DATA ANALYSIS SHEET

Date: 5/18/79

Laser line ID: P(22)

Sample Gas: H_2O in Air

Cell path length: 1.35891

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
17.66	20	1.776	2.627	0.676	0.288	25.2±0.2
15	17.6	1.904	2.627	0.725	0.237	25.2
12	14.26	2.100	2.627	0.799	0.165	25.2
9	10.2	2.230	2.627	0.849	0.121	25.2
BKG		2.627				25.2

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/5/79

Laser line ID: P(22)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.8	1.072	2.176	0.493	0.597	30.2 ± 0.2
20	22.0	1.300	2.176	0.597	0.434	30.2
15	17.6	1.526	2.176	0.701	0.299	30.2
BKG		2.176				30.2

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/28/79

Laser line ID: P(22)

Sample Gas: H_2O in Air

Cell path length: 1.18635 km

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	1.207	2.446	0.493	0.595	35.2±0.2
25	25.4	1.456	2.446	0.595	0.437	35.2
20	21.7	1.695	2.446	0.693	0.309	35.2
15	17.5	1.912	2.446	0.782	0.208	35.2
BKG		2.446				

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: P(24)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	1.262	2.200	0.574	0.468	25.1 ± 0.2
15	17.6	1.499	2.200	0.681	0.323	25.1
10	11.7	1.726	2.200	0.785	0.205	25.1
BKG		2.200				25.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/5/79

Laser line ID: P(24)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.8	1.163	2.158	0.539	0.521	30.2 ± 0.2
20	22.0	1.404	2.158	0.651	0.362	30.2
15	17.6	1.627	2.158	0.754	0.238	30.2
BKG		2.158				30.2

$$-\frac{\ell n\ T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/26/79

Laser line ID: P(24)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	1.495	3.408	0.439	0.695	34.8 ± 0.3
25	25.4	1.897	3.408	0.557	0.493	34.8
20	22	2.247	3.408	0.659	0.351	34.8
15	17.5	2.582	3.408	0.758	0.234	34.8
BKG		3.408				34.8

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: P(26)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	1.261	2.211	0.570	0.473	25.1±0.2
15	17.6	1.494	2.211	0.676	0.330	25.1
10	11.7	1.711	2.211	0.774	0.216	25.1
BKG		2.211				

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/26/79

Laser line ID: P(26)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	1.568	3.240	0.484	0.612	34.8 ± 0.3
25	25.4	1.803	3.240	0.556	0.495	34.8
20	22	2.210	3.240	0.682	0.322	34.8
15	17.5	2.539	3.240	0.784	0.206	34.8
BKG		3.240				34.8

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/18/79

Laser line ID: R(26)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.5	1.348	2.234	0.603	0.426	30 ± 0.3
20	21.6	1.632	2.234	0.731	0.265	30
15	17.2	1.880	2.234	0.842	0.145	30
BKG		2.234				30

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/6/79

Laser line ID: R(26)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.199	1.977	0.606	0.422	30.1±0.2
20	22.0	1.408	1.977	0.712	0.286	30.1
15	17.6	1.602	1.977	0.810	0.177	30.1
BKG		1.977				30.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/21/79

Laser line ID: R(26)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
29.5	28.5	1.115	2.078	0.537	0.524	35±0.2
24.7	25.4	1.315	2.078	0.633	0.385	35
20	22.1	1.578	2.078	0.760	0.231	35
14.5	17.2	1.795	2.078	0.864	0.123	35
BKG		2.078				35

$$\therefore \frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: R(28)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	1.461	1.942	[illegible]	0.240	25.1±0.2
15	17.6	1.666	1.942	0.858	0.129	25.1
10	11.7	1.722	1.942	0.887	0.101	25.1
BKG		1.942				25.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/6/79

Laser line ID: R(28)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	1.173	1.882	0.623	0.399	30.1±0.2
20	22.0	1.387	1.882	0.737	0.257	30.1
15	17.6	1.564	1.882	0.831	0.156	30.1
BKG		1.882				30.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/28/79

Laser line ID: R(28)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	1.142	2.414	0.473	0.631	35.2 ± 0.2
25	25.4	1.397	2.414	0.579	0.461	35.2
20	21.7	1.653	2.414	0.685	0.319	35.2
15	17.5	1.876	2.414	0.777	0.213	35.2
BKG		2.414				35.2

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/10/79

Laser line ID: R(30)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
20	22.0	1.238	1.955	0.633	0.385	25.1±0.2
15	17.6	1.464	1.955	0.749	0.244	25.1
10	11.7	1.528	1.955	0.782	0.208	25.1
BKG		1.955				25.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 7/6/79

Laser line ID: R(30)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ______

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
25	25.6	0.922	1.903	0.484	0.611	30.1±0.2
20	22.0	1.133	1.903	0.595	0.437	30.1
15	17.6	1.314	1.903	0.690	0.312	30.1
BKG		1.903				30.1

$$-\frac{\ln T}{\ell} = k$$

Comments:

DATA ANALYSIS SHEET

Date: 6/28/79

Laser line ID: R(30)

Sample Gas: H_2O in Air

Cell path length: 1.18635

Experiment performed by: ____________________

Partial Pressure (torr)	DP	I_S/I_{RS}	I_V/I_{VS}	Transmittance $(I_S/I_{RS})/(I_V/I_{VS})$	Absorption Coefficient (km^{-1})	Temperature (Front (C) (B) (^oC)
30	28.6	0.795	2.396	0.332	0.930	35.2±0.2
25	25.4	1.003	2.396	0.419	0.734	35.2
20	21.7	1.220	2.396	0.509	0.570	35.2
15	17.5	1.478	2.396	0.617	0.407	35.2
BKG		2.396				35.2

$$-\frac{\ln T}{\ell} = k$$

Comments: